Office for Nuclear Regulation

New Reactors Division – Generic Design Assessment

Step 4 Assessment of Conventional Fire Safety for the UK HPR1000 Reactor

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EXECUTIVE SUMMARY

This report presents the findings of my assessment of the Conventional Fire Safety aspects of the UK HPR1000 reactor design undertaken as part of the Office for Nuclear Regulation's (ONR) Generic Design Assessment (GDA). My assessment was carried out using the Pre-Construction Safety Report (PCSR) and supporting documentation submitted by the Requesting Party (RP).

The objective of my assessment was to make a judgement, from a Conventional Fire Safety perspective, on whether the generic UK HPR1000 reactor design could be built and operated in Great Britain, in a way that is acceptably safe and secure (subject to site specific assessment and licensing), as an input into ONR's overall decision on whether to grant a Design Acceptance Confirmation (DAC).

The scope of my GDA assessment was to review the safety aspects of the generic UK HPR1000 design by examining the claims, arguments and supporting evidence in the safety case. My GDA Step 4 assessment built upon the work undertaken in GDA Steps 2 and 3 and enabled a judgement to be made on the adequacy of the Conventional Fire Safety information contained within the PCSR and supporting documentation.

My assessment focussed on the following aspects of the generic UK HPR1000 safety case:

- Confirmation that the generic UK HPR1000 design can satisfy GB legal requirements for fire safety in building design.
- Benchmarking the structural arrangements and fire protection against relevant good practice to ensure adequate means of escape in case of fire are available for the occupants and the design incorporates adequate facilities for firefighters.
- Other non-structural fire protection measures, where these are claimed as mitigation to support means of escape.

The conclusions from my assessment are:

- The Fire Safety Strategy and other supporting documents, developed for each building, confirm that the generic UK HPR1000 design will satisfy GB legal requirements for fire safety in building design.
- Adequate structural fire protection and arrangements for means of escape are in place for the safety of occupants and suitable facilities are provided for firefighters.
- Where the design varies from relevant good practice, suitable alternative arrangements are provided to ensure risks are reduced ALARP.

These conclusions are based upon the following factors:

- A detailed and in-depth technical assessment, on a sampling basis, of the full scope of safety submissions at all levels of the hierarchy of the generic UK HPR1000 safety case documentation.
- Detailed technical interactions with the RP, alongside the assessment of the responses to the Regulatory Queries (RQs) raised during the GDA.

Overall, based on my assessment undertaken in accordance with ONR's procedures, the claims, arguments and evidence laid down within the PCSR and supporting documentation submitted as part of the GDA process present an adequate safety case for the generic UK

HPR1000 design. I recommend that from a Conventional Fire Safety perspective a DAC may be granted.

LIST OF ABBREVIATIONS

ALARP	As Low As Reasonably Practicable
BDA	Diesel Building A
BDB	Diesel Building B
BDC	Diesel Building C
BDU	Diesel Building U
BDV	Diesel Building V
BEJ	Extra Cooling System and Fire Fighting Water Supply Building
BFX	Fuel Building
BNX	Nuclear Auxiliary Building
BPX	Personnel Access Building
BRX	Reactor Building
BS 9999	British Standard 9999
BS 7974	British Standard 7974
BSA	Safeguard Building A
BSB	Safeguard Building B
BSC	Safeguard Building C
BWX	Radioactive Waste Treatment Building
CGN	China General Nuclear Power Corporation Ltd
DAC	Design Acceptance Confirmation
DMGL	Delivery Management Group Lead
GB	Great Britain
GDA	Generic Design Assessment
GNI	General Nuclear International Ltd.
GNSL	General Nuclear System Ltd.
HOW2	(ONR) Business Management System
HVAC	Heating, Ventilation and Air Conditioning
IAEA	International Atomic Energy Agency
iDAC	Interim Design Acceptance Confirmation
JPO	(Regulators') Joint Programme Office
MADA	Multi-Attribute Design Assessment
MCR	Main Control Room
MW	Megawatts
ONR	Office for Nuclear Regulation
PCSR	Pre-construction Safety Report
PWR	Pressurised Water Reactor
RCP	Reactor Coolant Pump

RGP	Relevant Good Practice
RI	Regulatory Issue
RO	Regulatory Observation
RP	Requesting Party
RPV	Reactor Pressure Vessel
RQ	Regulatory Query
SAP(s)	Safety Assessment Principle(s)
SFAIRP	So Far As Is Reasonably Practicable
SG	Steam Generator
TAG	Technical Assessment Guide(s)
TSC	Technical Support Contractor
UK	United Kingdom
WENRA	Western European Nuclear Regulators' Association

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1 INTRODUCTION

1.1 Background

1. This report presents my assessment conducted as part of the Office for Nuclear Regulation (ONR) Generic Design Assessment (GDA) for the generic UK HPR1000 design within the topic of Conventional Fire Safety.

2. The UK HPR1000 is a pressurised water reactor (PWR) design proposed for deployment in the UK. General Nuclear System Ltd (GNSL) is a UK-registered company that was established to implement the GDA on the UK HPR1000 design on behalf of three joint requesting parties (RP), i.e. China General Nuclear Power Corporation (CGN), EDF SA and General Nuclear International Ltd (GNI).

3. GDA is a process undertaken jointly by the ONR and the Environment Agency. Information on the GDA process is provided in a series of documents published on the joint regulators' website (www.onr.org.uk/new-reactors/index.htm). The outcome from the GDA process sought by the RP is a Design Acceptance Confirmation (DAC) from ONR and a Statement of Design Acceptability (SoDA) from the Environment Agency.

4. The GDA for the generic UK HPR1000 design followed a step-wise approach in a claims-argument-evidence hierarchy which commenced in 2017. Major technical interactions started in Step 2 which focussed on an examination of the main claims made by the RP for the UK HPR1000. In Step 3, the arguments which underpin those claims were examined. The Step 2 reports for individual technical areas, and the summary reports for Steps 1, 2 and 3 are published on the joint regulators' website. The objective of Step 4 was to complete an in-depth assessment of the evidence presented by the RP to support and form the basis of the safety and security cases.

5. The full range of items that form part of my assessment is provided in ONR's GDA Guidance to Requesting Parties (Ref. 1). These include:

- Consideration of issues identified during the earlier Step 2 and 3 assessments.
- Reviewing details of the RP's design controls and quality control arrangements to secure compliance with the design intent.
- Assessing arrangements for ensuring and assuring that safety claims and assumptions will be realised in the final as-built design.
- Resolution of identified nuclear safety and security issues, or identifying paths for resolution.

6. The purpose of this report is therefore to summarise my assessment in the Conventional Fire Safety topic which provides an input to the ONR decision on whether to grant a DAC, or otherwise. This assessment was focused on the submissions made by the RP throughout GDA, including those provided in response to the Regulatory Queries (RQs) I raised.

1.2 Scope of this Report

7. This report presents the findings of my assessment of the conventional fire safety of the generic UK HPR1000 design undertaken as part of GDA. I carried out my assessment using the Pre-Construction Safety Report (PCSR) (Ref. 3) and supporting documentation submitted by the RP. My assessment was focussed on

considering whether the generic safety case provides an adequate justification for the generic UK HPR1000 design, in line with the objectives for GDA.

1.3 Methodology

8. The methodology for my assessment follows ONR's Guidance On The Mechanics Of Assessment, NS-TAST-GD-096 (Ref. 4).

9. My assessment was undertaken in accordance with the requirements of ONR's How2 Business Management System (BMS).

10. I benchmarked the generic UK HPR1000 design against British Standard 9999: 2017 Code of Practice for Fire Safety in the design, management and use of buildings, (Ref. 5). When departures from this standard were identified, I employed the methodology described in British Standard 7974: Code of practice for the application of fire safety engineering principles to the design of buildings, (Ref. 6), to assess the claims, arguments and evidence supporting the alternative mitigation arrangements and ensure risk was adequately controlled and reduced As Low As Reasonably Practicable (ALARP).

2 ASSESSMENT STRATEGY

11. The strategy for my assessment of the Conventional Fire Safety aspects of the generic UK HPR1000 design and safety case is set out in this section. This identifies the scope of the assessment and the standards and criteria that have been applied.

2.1 Assessment Scope

12. A detailed description of my approach to this assessment can be found in assessment plan ONR-GDA-UKHPR1000-AP-19-005, Revision 0, (Ref. 7).

13. I considered all the main submissions within the remit of my assessment scope, to various degrees of breadth and depth. I chose to concentrate my assessment on those aspects that I judged to have the greatest life safety significance, or where the hazards appeared least well controlled. My assessment was also influenced by the claims made by the RP, my previous experience of similar systems for reactors and other nuclear facilities, and any identified gaps in the original submissions made by the RP. A particular focus of my assessment has been the RQs I raised as a result of my on-going assessment, and the resolution thereof.

2.2 Sampling Strategy

14. In line with ONR's guidance (Ref. 4), I chose a sample of the RP's submissions to undertake my assessment. The main themes considered were.

- My assessment focused on those areas presenting the greatest life safety risk. These are locations in the building where the design varies from conventional expectations for means of escape in case of fire. I assessed the structural fire protection and internal layout arrangements of buildings on the nuclear island, to ensure the design enables the licensee to comply with GB legal requirements for fire safety and provide adequate means of escape for the occupants in case of fire. Additionally, I assessed the design to ensure adequate protection and suitable facilities are in place for firefighters.
- Non-structural fire protection arrangements were assessed, when they were relevant and provided supporting mitigation for design features which do not meet recommendations contained within codes of practice in design of buildings for fire safety.
- My assessment included Fire Strategy documents and other supporting material for the following individual buildings, submitted in Step 4 of GDA.
    - Nuclear Auxiliary Building.
    - Radioactive Waste Building.
    - Essential Service Water Pumping Station.
    - Diesel Generator Building.
    - Personnel Access Building.
- The scope also included review of Fire Strategy documents and Gap Management Reports, submitted during Step 3, and revised during Step 4 of GDA.
    - Reactor Building.
    - Safeguard Building.
    - Fuel building.
- I reviewed the study described in the document 'Analysis of Firefighting Shafts and Staircase Pressurization Systems' (Ref. 8), to assess the effect of building

ventilation systems on smoke control in staircase escape routes within the Reactor Building and other facilities.

- I assessed the fire engineering contained within the full responses to all RQs, updated versions of Fire Safety Strategy documents and revisions of Gap Management Reports, which were submitted throughout the GDA process.

2.3 Out of Scope Items

15. The following items were outside the scope of my assessment.

- Detailed equipment specifications for fire detection and warning systems, emergency lighting, intelligent evacuation signage, water supplies for firefighting and fixed firefighting installations were not included in GDA scope because they are non-structural provisions which are site specific and will be reviewed during site-specific stages.
- Technical Galleries are not included in my Step 4 Assessment Plan, because the layout is site specific. A Conventional Fire Safety assessment of the Technical Galleries will be undertaken during site-specific stages.

2.4 Standards and Criteria

16. The relevant standards and criteria adopted within this assessment are principally the relevant national and international standards, and relevant good practice informed from existing practices adopted on nuclear licensed sites in Great Britain. The key national and international standards and guidance are detailed within this section. Relevant good practice (RGP), where applicable, is cited within the body of the assessment.

2.4.1 Safety Assessment Principles

17. The Safety Assessment Principles (Ref. 2) that are usually used as the basis of assessment by ONR relate only to nuclear safety, radiation protection and radioactive waste management. Conventional hazards including conventional fire safety associated with a nuclear facility are excluded, except where they have a direct effect on nuclear safety or radioactive waste management. The SAPs are therefore not germane to my assessment and have not been referenced.

2.4.2 Technical Assessment Guides

18. The following Technical Assessment Guides were used as part of this assessment (Ref. 4):

- NS-TAST-GD-051, *The Purpose, Scope and Content of Nuclear Safety Cases.*
- NS-TAST-GD-005, *ONR Guidance on the Demonstration of ALARP.*

2.4.3 National and International Standards and Guidance

19. The standards I have used to judge the adequacy of the RP’s submissions in the discipline of Conventional Fire Safety have been the primary national standards contained in published guidance for fire safety in the design and management of buildings and requirements of GB fire safety legislation. These documents are: -

- British Standard 9999: 2017, the Code of Practice for Fire Safety in the Design Management and Use of Buildings (Ref. 5).
- British Standard 7974; - Application of fire safety engineering principles to the design of buildings (Ref. 6).
- Regulatory Reform (Fire Safety) Order 2005 (Ref. 9).

20. The following international standards and guidance were used as part of this assessment.

   - Not applicable, I did not use international standards or guidance in my assessment.

2.5 Use of Technical Support Contractors

21. I did not utilise any Technical Support Contractors to assist with my assessment.

2.6 Integration with Other Assessment Topics

22. GDA requires the submission of an adequate, coherent, and holistic generic safety case. Regulatory assessment cannot be carried out in isolation as there are often issues that span multiple disciplines. I have therefore worked closely with a number of other ONR inspectors to inform my assessment. The key interactions were:

   - Discussions with ONR Security regarding escape routes within buildings and importance of maintaining ready egress through final exit doors in the generic UK HPR1000 design to ensure safety for occupants in case of fire. As part of normal business throughout the review process, the RP assessed security implications arising from potential design changes proposed to improve fire safety. ONR Security, during their assessment of the generic UK HPR1000 security case, took the lead regarding the RP's approach to the identification of vital areas.

3 REQUESTING PARTY'S SAFETY CASE

3.1 Introduction to the Generic UK HPR1000 Design

23. The generic UK HPR1000 design is described in detail in the PCSR (Ref. 3). It is a three-loop PWR designed by CGN using the Chinese Hualong technology. The generic UK HPR1000 design has evolved from reactors which have been constructed and operated in China since the late 1980s, including the M310 design used at Daya Bay and Ling'ao (Units 1 and 2), the CPR1000, the CPR1000$^+$ and the more recent ACPR1000. The first two units of CGN's HPR1000, Fangchenggang Nuclear Power Plant (NPP) Units 3 and 4, are under construction in China and Unit 3 is the reference plant for the generic UK HPR1000 design. The UK HPR1000 design is claimed to have a lifetime of at least 60 years and has a nominal electric output of 1,180 MW.

24. The reactor core of the generic UK HPR1000 design contains zirconium clad uranium dioxide (UO_2) fuel assemblies and reactivity is controlled by a combination of control rods, soluble boron in the coolant and burnable poisons within the fuel. The core is contained within a steel Reactor Pressure Vessel (RPV) which is connected to the key primary circuit components, including the Reactor Coolant Pumps (RCPs), Steam Generators (SGs), pressuriser and associated piping, in the three-loop configuration. The design also includes a number of auxiliary systems that allow normal operation of the plant, as well as active and passive safety systems to provide protection in the case of faults, all contained within a number of dedicated buildings.

25. The reactor building houses the reactor and primary circuit and is based on a double-walled containment with a large free volume. Three separate safeguard buildings surround the reactor building and house key safety systems and the main control room. The fuel building is also adjacent to the reactor and contains the fuel handling and short-term storage facilities. Finally, the nuclear auxiliary building contains a number of systems that support operation of the reactor. In combination with the diesel, personnel access, and equipment access buildings, these constitute the nuclear island for the generic UK HPR1000 design.

3.2 The Generic UK HPR1000 Safety Case

26. In this section I provide an overview of the Conventional Fire Safety aspects of the generic UK HPR1000 safety case as provided by the RP during GDA. Details of the technical content of the documentation and my assessment of its adequacy are reported in the subsequent sections of my report.

27. The RP submitted a PCSR (Ref. 3) and supporting references on commencement of Step 3 of GDA, which outline the nuclear safety case for the generic UK HPR1000 design. This was supplemented throughout the Step by further submissions, including responses to my regulatory questions. This section presents a high-level summary of the RP's case and identifies the main documents which formed the basis of my assessment.

The case presented by the RP can be summarised as follows:

- The fire safety case presented by the RP is contained within a hierarchical suite of documents that developed throughout the GDA process. The approach taken to defining the generic UK HPR1000 fire safety arrangements commence with Chapter 25 of the PCSR (Ref. 3) which describes the overall policy to provide a fire safe power plant. The PCSR is supported by the site-wide 'High-Level Fire Safety Strategy' document, (Ref. 10), which identifies the standards to be adopted and the means of implementing the fire safety measures. At an intermediate level, each building has a dedicated 'Fire Safety Strategy' document which describes the fire protection arrangements based upon building design, use, occupancy, and fire load characteristics. These premises-specific Fire Safety Strategy documents describe the general management of fire safety issues and fire engineering principles adopted to control risk. At the lowest level of the hierarchy, individual compartments are subject to detailed fire engineering assessments, where considered necessary. These detailed assessments are undertaken if compliance with codes of practice in building design is not achieved or means of escape is challenging.

- The fire safety case includes demonstrating that the structural design of each building complies with GB standards and expectations for fire safety.
- Overall, the suite of documents aims to demonstrate that the generic UK HPR1000 design has suitable arrangements to protect people from the danger of fire. Life safety is achieved by presenting a strategy that confirms compliance with appropriate legislation, selects suitable standards and adopts relevant industry good practice.
- Where it is impractical to fully meet the expectations of building guidance in fire safety and achieve the safety functions of an operating nuclear power plant, the RP implements alternative mitigation arrangements appropriate to the level of fire risk. A structured management process, employing fire engineering principles is used to produce a design that protects people from the danger of fire and demonstrates risk is fully assessed, controlled, and reduced ALARP.

28. The main documentation that has formed the basis for my assessment is presented in Refs. 3, 8 and 10 to 22. The content of these documents is outlined below:

- The Pre-Construction Safety Report HPR/GDA/PCSR/0025 Revision 002, Chapter 25, (Ref. 3), proposes a strategy for compliance with GB legal requirements and adequate arrangements for protection of people from the danger of fire. The document references GB legislation and identifies relevant good practice and published GB guidance for fire safety in the design of buildings.
- The 'High Level Fire Safety Strategy', Revision C, (Ref. 10), applies to all facilities on the nuclear island and it describes, in greater detail than the PCSR, how the generic UK HPR1000 design will achieve compliance with GB legal requirements. This document defines the approach taken to ensure the safety of occupants for each premises and takes into account the specific features of individual facilities that require discrete fire protection arrangements.
- The 'Methodology for Gap Management in Conventional Fire Safety Area' (Ref. 11), details the fire engineering principles adopted to produce alternative fire safety measures when the application of BS 9999, (Ref. 5), is impractical. The document provides a structured process for the identification, management, and resolution of departures from compliance with codes of practice.
- Fire safety strategy documents have been produced for each individual building on the nuclear island. These documents describe the fire safety concepts employed to protect people and how the building is expected to perform should a fire occur. The strategy considers the relevant features of each building; its use, occupancy, fire load and growth characteristics, protective measures and structural arrangements supporting means of escape. Each fire compartment

is considered individually and benchmarked against building design guidance for fire safety.

- During Step 3 of the GDA process, fire strategies were supported by a separate document entitled a 'Gap Management Report' which described the fire engineering assessment and mitigation for features that did not meet codes of practice for fire safety in building design. Later, commencing at the start of Step 4 of GDA, Fire Strategies comprised a single comprehensive document which incorporates the fire engineering detail originally contained within Gap Reports.

- Throughout the GDA process, a number of Fire Safety Strategy documents and Gap Management Reports were updated due to development of an improved risk assessment and/or the introduction of building design modifications to enhance fire safety. Whilst all documents were reviewed on their original submission, and feedback provided to the RP, only the revisions detailed below form the subject of my assessment of conventional fire safety. Earlier versions of the documents now contain superseded risk assessments and fire engineering which is no longer relevant to the proposed design.

  My final assessment of conventional fire safety for the generic UK HPR1000 design is based upon the following submissions.

  - Fire Strategy for the Reactor Building, Rev. B, (Ref. 12).
  - Gap Management Report for the Reactor Building, Rev. B, (Ref. 13).
  - Fire Strategy for the Fuel Building, Rev. A, (Ref. 14).
  - Gap Management Report for the Fuel Building, Rev. B, (Ref. 15).
  - Fire Strategy for the Safeguard Buildings, Rev. A, (Ref. 16).
  - Gap Management Report for the Safeguard Buildings, Rev. C, (Ref. 17).
  - Fire Strategy for the Nuclear Auxiliary Building, Rev. B, (Ref. 18).
  - Fire Strategy for the Radioactive Waste Treatment Building, Rev. B, (Ref. 19).
  - Fire Strategy for the Diesel Generator Buildings, Rev. B, (Ref. 20).
  - Fire Strategy for the Personnel Access Building, Rev A, (Ref. 21).
  - Fire Strategy for the BEJ Building, Rev B, (Ref. 22).

- To assess the impact from ventilation systems on protection of fire escape staircases from smoke ingress, I used the results of a study contained within the document 'Analysis of Firefighting Shafts and Staircases Pressurization Systems', Rev A, (Ref. 8). The study was undertaken following the issue of an RQ for the Reactor Building, but the findings are applicable to a number of facilities on the nuclear island.

- The 'ALARP Demonstration Report for Conventional Fire Safety', Revision C, (Ref. 23) provides an overview of fire engineering undertaken by the RP and a useful summary of the results from fire safety assessment work. The ALARP Report records the structural alterations arising from fire safety assessments undertaken during the GDA process. The document also identifies the need for future fire safety assessments in the site-specific stages phase which are not within the scope of a generic design assessment.

4 ONR ASSESSMENT

4.1 Structure of Assessment Undertaken

29. My approach to the assessment of fire safety for the generic UK HPR1000 design consisted of a detailed review of the major facilities comprising the nuclear island. Buildings with the highest potential life safety risk from fire, were selected for assessment first and were included in my Step 3 GDA Assessment Plan, (Ref. 24). The Reactor Building, Safeguard Buildings and Fuel Building were chosen for earliest review because it was anticipated that their specialised nuclear function would present the greatest design challenges to conventional fire safety. The remaining buildings on the nuclear island were included in my Step 4 GDA Assessment Plan, (Ref. 25); these were the Nuclear Auxiliary Building; Radioactive Waste Treatment Building; Diesel Buildings; Personnel Access Building, and Extra Cooling System and Firefighting Water Building (BEJ Building). All work identified in the Step 3 and Step 4 GDA Assessment Plans was completed within the GDA timeframe, including the ventilation study (Ref. 8), which was an additional item arising from a response to an RQ.

30. To gain greater understanding of the RP's fire protection arrangements on an operating nuclear power station, I visited Yangjiang Nuclear Power Plant, Guangdong, China. I noted the enhanced fire protection provided by cable wrapping, very high standards of housekeeping and much greater priority given to early firefighting intervention than is typical in Great Britain. However, I observed that staircases, used as primary means of escape in China, have less structural fire protection and do not always discharge directly to a place of safety or a protected area.

31. I assessed document submissions for each building individually; appraising structural arrangements for their impact on means of escape, examining the provision of facilities for firefighters and ensuring the final design enables the licensee to satisfy the requirements of the Regulatory Reform (Fire Safety) Order 2005, (Ref. 9). I also considered the benefit offered by non-structural fire safety provisions, where these features are presented as mitigation for departures from best practice in building design. In addition to the individual building assessments, for those facilities which are connected to one another I also considered the holistic impact on means of escape. The result of my assessment of each building is presented in subsequent paragraphs of this report.

32. A systematic approach was taken in building assessment for fire safety design, commencing with a review of documents. Where it was helpful to understand layout arrangements, I examined samples of fire zone drawings. Following assessment of the RP's submissions, I attended workshops to provide feedback, clarify understanding of proposals and discuss technical issues. I raised RQs at any point in the assessment process when I identified areas that required further fire engineering development or improvements to risk assessment. When enhanced fire safety arrangements or better risk assessments led to document updates, the review process was repeated until all items were satisfactorily closed out for GDA.

33. I reviewed each building against British Standard 9999 (Ref. 5), the benchmark for relevant good practice in fire safety design. I assessed the number, arrangement and fire protection of escape routes and considered the occupancy, fire load characteristics and operational use of each compartment in relation to the means of escape and the availability of fire protection systems. I also took into account the provision and standard of structural features, automatic fire detection, ventilation systems and management arrangements.

34. Detailed fire safety assessments of individual buildings commenced during Step 3 of the GDA process. At that time, the Requesting Party produced two documents for each facility, a Fire Safety Strategy document, and a Gap Management Report. The Fire Safety Strategy mainly describes the general fire protection arrangements within the building and demonstrates the means to achieve compliance with UK legislation. The Gap Management Report identifies specific departures from codes of practice in fire safety design of individual fire compartments and describes the process to assess and control the risk in specific areas. Read in conjunction with one another, these two documents provide a full account of fire safety arrangements for each facility. Later, in Step 4 of GDA, these two documents were combined, and the Requesting Party submitted a single comprehensive Fire Safety Strategy which incorporates full details of the process to manage departures from prescriptive guidance. This change in format is described here, to explain the sequence of reporting on fire safety issues, contained in the paragraphs below.

35. My assessment focused on those areas of building design presenting the greatest life safety risk from fire, particularly locations presenting challenging means of escape in case of fire. In many cases, these conditions are a result of arrangements designed to achieve radiological protection or building features to ensure nuclear safety and security. Gap Management Reports and Fire Safety Strategy documents identify these departures from codes of practice in fire safety design and describe the optioneering undertaken to develop credible mitigation. This includes a fire engineering assessment of the proposed solution that demonstrates risks are reduced ALARP. I reviewed the RP's fire engineering procedure to manage risk gaps, assess the scale of departures, and the claims and arguments supporting the optioneering of alternative mitigation. In addition to the gaps documented within the RP's submissions, I raised RQs at any point in the assessment process to gain further information and confirm all departures from compliance with relevant good practice were identified and suitably addressed. Throughout this report, I use the term 'fire engineering' to mean the application of scientific and engineering principles, codes of practice, and expert judgment. This expertise is based on an understanding of the phenomena and effects of fire and of the reaction and behaviour of people to fire, to protect people, property, and the environment from the destructive effects of fire. My assessment also considered the impact of fire engineering on other safety and security disciplines, to ensure that all risks are reduced ALARP.

36. When submissions were not clear or the fire engineering was not convincing, I raised RQs to obtain further information. In some cases, the additional detail contained in the response or submission of an improved risk assessment was sufficient to close out the query. In other responses to RQs, the RP completely removed the gap by implementing a design modification that improved means of escape and met the recommendations within BS 9999, (Ref. 5). Fire Strategy documents were updated to consolidate the outcome, or additional information arising, from responses to RQs. An overview of the full response to every RQ raised for each building is described in the sections on Technical Assessment below.

37. Each building in my Conventional Fire Safety assessment is described individually in subsequent paragraphs, but the reporting format is the same in each case. Document submissions for each facility and relevant RQs are listed chronologically, and the key fire engineering principles supporting the fire safety case are included for each building.

38. Throughout the GDA process, various Fire Safety Strategy documents and Gap Management Reports were updated due to building design modifications or submission of improved risk assessments. Whilst all documents were reviewed on

their original submission, only the key features of the fire engineering contained in the current documents (listed in section 3.2 above) are summarised in my Conventional Fire Safety assessment and reported in subsequent paragraphs. Earlier versions of Fire Strategies and Gap Management Reports contain superseded information which is no longer relevant to the proposed design and is not included in this report to avoid unnecessary confusion. However, when any document resulted in an RQ, details of the full response to the query are described to give context to the progress of my Conventional Fire Safety assessment.

39. The RP developed a 'Gap Management' process to resolve departures from relevant good practice. This process includes a procedure for comparing the impact of design changes on the generic UK HPR1000 design arising from optioneering of potential fire engineering solutions and to give accountability for the final design choices. Fire Safety Strategy documents and Gap Management Reports typically identify several options to manage each risk gap. All credible options are attributed a numerical score for impact on life safety, nuclear safety, cost, and operational activity; various weighting factors are applied to each of these categories to produce an overall score for each option. The RP's design solution is selected by the option achieving the highest total score. Whilst the multi-attribute design assessment is a useful tool for recording the decision-making process, I did not make use of this process when evaluating the most suitable fire engineering option. My independent assessment used personal experience of relevant industry good practice, application of fire engineering principles, and cognisance of nuclear safety and security requirements. Despite these alternative approaches, there was overall, an agreement throughout the GDA process in the results of the optioneering produced by the impact analysis. Where there was a misalignment of opinion, I raised an RQ.

4.2 Reactor Building Fire Safety Design Assessment

4.2.1 Assessment

40. My assessment of the Reactor building refers to BRX. This building is located at the centre of the nuclear island and is surrounded by other independent buildings which prevent direct access or egress from BRX. The building height ranges from -5.0m to +33.2m and although BRX has ten floor levels these are not all divided into separate fire compartments. Two pressurised fire protected staircases are available for escape, but lobby protection is largely absent. The main staircase connects to Safeguard Building C via a personnel airlock at +1.2m. The auxiliary staircase connects to the Fuel Building by an emergency airlock at +17.5m and unlike the main staircase it is not fire protected at basement levels. Both airlocks can automatically release to assist evacuation in case of fire. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage. Emergency lighting is fitted throughout the facility. Fire load in the Reactor Building consists mainly of lubricating oil and insulation on electrical cables and equipment. Structural fire compartmentation that separates the building into individual fire resisting areas is not fully achieved in BRX due to nuclear safety requirements for control of hot gas release. This restriction on the use of physical barriers to prevent fire spread is managed by geometric separation and strict control of combustibles. Occupancy of BRX only occurs during outage when the building may accommodate about 100 trained staff. The fire risk profile, categorised by BS 9999 (Ref. 5), is A3 due to potential fast fire growth rate.

41. Additional fire protection measures are available in BRX. Where necessary, two-hour fire-resistant cable wrapping is applied to reduce effective fire load. Fixed firefighting water sprinkler systems are located in the annulus and installed for each reactor coolant pump to protect cable trays. A water flooding system is available for

the active carbon filters.

42. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety assessment of the Reactor Building. Departures from this guidance are also recorded as a gap in the document submissions by the RP. I assessed each gap to ensure suitable mitigation is in place and risks are adequately controlled.

43. The Reactor building was the first facility selected for conventional fire safety design assessment because it was anticipated that the specialised function of the BRX would present the greatest challenges to means of escape. Assessing the perceived greatest risk first allowed maximum use of time within GDA to resolve any issues arising.

44. Detailed assessment of the Reactor Building started in Step 3 of the GDA process when the Requesting Party submitted the Gap Management Report for Reactor Building - Rev A (Ref. 27), in February 2019. The purpose of that document is to record details of the design that depart from the recommendations within BS 9999 (Ref. 5), and to apply the fire engineering methodology to reduce the risk gap or demonstrate that the existing fire safety arrangements are adequate, and that risks are already reduced ALARP.

45. I assessed the fire engineering contained in the Gap Report and gave feedback to the RP at a fire safety design workshop in Shenzhen, China. I challenged the selection of mitigation measures in the Gap report and issued Regulatory Query RQ-UKHPR1000-0225 - Fire Safety Update to Reactor Building Gap Report, (Ref. 28). In response, the RP advised that a revision to the original Gap Report was already in development which addressed several of my observations. Subsequently, the full response to the RQ and submission of revision B of the Gap Report superseded and closed out issues arising from the initial Gap Report for the Reactor Building, revision A (Ref. 27).

46. RQ-UKHPR1000-0225, Fire Safety Update to Reactor Building Gap Report, (Ref. 28). This RQ requested further information in three main areas, to further explain the fire engineering proposals in the initial Gap Management Report for BRX: -

1. ‘Describe how the fire engineering is robust and not undermined by the challenge of providing low-cost additional mitigation.’

   Several departures from relevant good practice identified in the initial Gap Report contained claims that risks were reduced ALARP following implementation of fire engineered solutions. I challenged these claims particularly where the risk gap remained large, and the addition of separate low-cost measures could reduce the gap and enhance personnel safety through defence in depth.

   Revision B of the Reactor Building Gap Management Report, (Ref. 13), contained improved fire engineering but did not fully resolve my observations raised in the RQ and led to a subsequent RQ-UKHPR1000-0349, (Ref. 28). The challenge of providing low-cost additional mitigation was finally closed out through submission of the Reactor Building Fire Safety Strategy to revision B, (Ref. 12), which contained additional information and is described in more detail below.

2. ‘Describe the process to manage and resolve high priority, fire life safety issues which emerge during the risk assessment.’

The initial Gap Report describes that the Reactor Building could contain a maximum of 100 people and that escape is available through two airlocks, but the Report did not demonstrate these exits were sufficient to achieve evacuation within a safe time.

Revision B of the Gap Report (Ref. 13) gave more fire engineering detail but did not fully close out issues raised in RQ-UKHPR1000-0225, (Ref.28). To gain confidence that basic principles of means of escape were correctly applied, I raised a follow-on RQ-UKHPR1000-0282, (Ref. 28). The full response to this RQ finally closed out the line of enquiry by including standard calculations of exit widths. These proved that the existing design arrangements are satisfactory for the maximum number of people expected in the building.

3. ‘Demonstrate the effectiveness of the scoring system to produce an ALARP choice that is convincing.’

The updated Gap Management Report, revision B, (Ref. 13), described in more detail the Multi-Attribute Design Assessment (MADA) methodology used in the Impact Analysis challenged by this query. The scoring system was developed by the RP to identify and manage gaps from compliance with prescriptive guidance and assist in demonstrating risks are reduced ALARP. I consider the MADA method a useful tool that provides a consistent method of recording the RP’s priorities allocated to fire protection measures. However, in my assessment of the most appropriate mitigation, I independently assessed the advantages and disadvantages presented by each option generated by the RP’s fire engineering review. Using my own experience of relevant industry good practice, application of fire engineering principles, and cognisance of nuclear safety and security requirements, I formed my own view of the ALARP solution. Despite this use of alternative approaches, there was broad agreement in the results of the optioneering undertaken in the impact analysis. Where there was a misalignment of opinion, I raised an RQ. I adopted this approach in assessing the best fire safety option not only for the Reactor Building but also all other building assessments throughout the whole GDA process for the generic UK HPR1000 design.

The close alignment of my assessment and the results of the RP’s evaluation methodology for determining the ALARP option confirmed the effectiveness of the RP’s process and satisfactorily closed out the RQ.

47. Reactor Building Fire Strategy, Rev A, (Ref. 29), reviewed in March 2019 proposed evidence that the generic UK HPR1000 design can achieve compliance with GB law by demonstrating risks from fire are fully assessed and adequately controlled. The document describes conventional fire safety arrangements and also contains details of the enhanced measures that support the claims contained within the ‘Gap Management Report’. This document was later superseded by the submission of revision B of the Reactor Building Fire Safety Strategy in September 2020, (Ref. 12).

48. Reactor Building Gap Management Report, Rev B, (Ref. 13). Reviewed in April 2019. My assessment of the fire engineering issues contained in this Gap Management Report, Rev B, follows in subsequent paragraphs, after detailing my observations on relevant RQs. Regulatory Query Tracking Sheet, (Ref. 28), provides details of all RQs issued by ONR for UK HPR1000, throughout the GDA process for Conventional Fire Safety and all other disciplines.

This updated Gap Report improved the fire engineering assessments contained in the initial document; however, revision B did not provide a full explanation of several issues. Consequently, I raised five RQs to gain further details;

RQ-UKHPR1000-0282-Means of Escape.
RQ-UKHPR1000-0283-Escape Modelling.
RQ-UKHPR1000-0284-Evacuation Delay to allow Investigation of Fire Alarm.
RQ-UKHPR1000-0349-Additional Fire Protection to strengthen ALARP Case.
RQ-UKHPR1000-0350-Fire protection arrangements for staircases.

49. Close out of queries raised in the five RQs arising directly from the Gap Report only occurred after two further follow-on RQs were issued. These additional RQs were,

RQ-UKHPR1000-0980-Ventilation Report.
RQ-UKHPR1000-1266-Ventilation Analysis – Reactor Building.

As part of the response to RQ-UKHPR1000-0980, a study into ventilation systems was undertaken by the RP and submitted as ‘Analysis of Firefighting Shafts and Staircases Pressurization Systems - Rev A. (Ref. 8).

50. RQ-UKHPR1000-0282. Means of Escape. (Ref. 28).
This RQ asked for justification that the means of escape provided by the two airlocks giving access to BRX was adequate for the foreseeable maximum number of people who may be present. Revision B of the Gap Report did not provide sufficient information to demonstrate these exits were wide enough to achieve evacuation within a safe time. The full response to this RQ followed relevant good practice by presenting a calculation of minimum escape route width; that demonstrated that the smallest single airlock could provide adequate means of escape.

The additional fire engineering information given in the full response, closed-out the issues raised by this RQ and demonstrates that the existing arrangements are satisfactory.

51. RQ-UKHPR1000-0283. Escape Modelling. (Ref. 28),
This RQ asked for an explanation behind the occupant escape modelling described in Appendix B of the Gap Management Report for the Reactor Building, Rev. B, (Ref. 13). The RQ challenged assumptions on ventilation conditions and the effect of varying the locations of fire in the simulations. Additionally, the modelling of escape time appeared overly conservative in the assumption of occupant behaviour when selecting an escape route.

The full response to the RQ clarified basic means of escape factors regarding; compartment height; strict management control of combustibles, and; confirmed that fire load is restricted to insulation on electrical cables which is selected for low fire growth rate and smoke evolution. It also confirmed that the fire dampers in the ventilation system close on activation of automatic fire detection, thereby reducing the rate of smoke spread within some escape routes.

The additional detail provided in the full response gave sufficient information to demonstrate that the existing means of escape arrangements were satisfactory. Consequently, I considered the need for fire modelling was rendered unnecessary and the RQ was satisfactorily closed out by conventional fire engineering assessment methodology alone.

52. RQ-UKHPR1000-0284. Evacuation Delay to allow Investigation of Fire Alarm. (Ref. 28).

This request for further information challenged the need to investigate a potential fire, following the activation of a smoke detector before sounding a building evacuation. Whilst a predetermined investigation period before raising a full building fire warning alarm is an accepted practice, I questioned the application of this approach in a facility where there are extended escape distances. The full response to the RQ adequately explained that activation of a fire detector will result in immediate local area alarm, warning people to evacuate from relevant compartments without delay. Elsewhere in the building, after elapse of a pre-set investigation time of 120 seconds, a full facility fire evacuation warning is sounded.

The fire detection arrangements described in Reactor Building Fire Strategy document, revision B, (Ref. 12), and the greater detail given in the full response to RQ-UKHPR1000-0284 - Evacuation Delay to allow Investigation of Fire Alarm. (Ref. 28), fully close out this issue for GDA. During site-specific stages, details of the fire compartments comprising the definition of 'local area' will be addressed as part of normal regulatory business.

53. RQ-UKHPR1000-0349. Additional Fire Protection to strengthen ALARP Case for the Reactor Building. (Ref. 28).
I challenged several claims in the Gap Report that risks were reduced ALARP, particularly where the risk gap remained large, and potential low-cost measures could reduce the gap further and improve personnel safety through defence in depth. The full response to the RQ explained that the design includes enhanced mitigation to further reduce risk and that the detail describing these additional control measures is included in the update to the Reactor Fire Strategy document.

Submission of revision B of the Fire Safety Strategy for the Reactor Building, (Ref. 12), confirmed the fire safety arrangements to support the mitigation as claimed in the full response and closes out the issues raised by this RQ.

54. RQ-UKHPR1000-0350: 'Fire protection arrangements for staircases within the Reactor Building', (Ref. 28).
I requested fire engineering justification for shortfalls in the protection of vertical escape routes due to the absence of fire resisting lobby access to staircases. The full response to the RQ claimed existing arrangements met ALARP due to; high standards of structural fire resistance (2 hours); alternative directions of escape which produce broadly compliant travel distances in BRX, and; the advantages of staircase pressurisation arising from the Containment Sweeping and Blowdown Ventilation System. Although this information clarified the claims on fire protection measures, there was insufficient information in the full response to assess the effectiveness of the ventilation over-pressure in keeping the staircases free from smoke. Subsequently, I raised RQ-UKHPR1000-0980 asking for more information about the ventilation system.

Close out of the original RQ-UKHPR1000-0350 and follow-up RQ-UKHPR1000-0980 was finally achieved after submission of 'Analysis of Firefighting Shafts and Staircases Pressurization Systems - Rev A', (Ref. 8), and the full response to a further RQ-UKHPR1000-1266 which confirmed the existing ventilation system arrangements were sufficient to provide adequate overpressure and maintain smoke free escape staircases in the Reactor Building.

55. RQ-UKHPR1000-0980. Ventilation Report, (Ref. 28). The purpose of this RQ was to highlight the information I required to assess the contribution of pressurisation systems in protecting escape staircases, and to clarify the scope of the Ventilation Report. The RQ requested a review of the relevant sections of the generic UK HPR1000 Fire Safety Strategy documents and Gap Management Reports to determine the effectiveness of smoke control arrangements within each facility

against the requirements of BS EN 12101-6:2005, (Ref. 30), for relevant firefighting shafts. The RQ emphasised particular interest in staircases that do not have the full suite of fire protection measures described in BS 9999. (Ref. 5). Submission of document 'Analysis of Firefighting Shafts and Staircases Pressurization Systems - Rev A', (Ref. 8), closed out this RQ but insufficient detail for BRX led to a follow-up RQ-UKHPR1000-1266-Ventilation Analysis-Reactor Building, (Ref. 28). The full response to RQ-UKHPR1000-1266 finally closed out this line of enquiry by demonstrating the existing arrangements were sufficient to provide the protection required to meet relevant sections of BS EN 12101-6:2005, (Ref. 30), recommendations for static overpressures in firefighting staircases.

56. Analysis of Firefighting Shafts and Staircases Pressurization Systems - Rev A, (Ref. 8). This study of ventilation in escape staircases provided the information requested in RQ-UKHPR1000-0980 to determine the effectiveness of smoke control arrangements within each facility against the requirements of BS EN 12101-6:2005, (Ref. 30), for relevant firefighting shafts, particularly staircases which do not have the full suite of fire protection measures described in BS 9999 (Ref. 5). This Analysis document provides a comprehensive assessment of the HVAC system in meeting relevant good practice for design and performance specification. The approach taken is systematic, uses appropriate guidance standards and confirms that the existing fire protection arrangements meets ALARP for Controlled Areas.

For Supervised Areas, the existing fire protection arrangements are satisfactory. However, the study has identified that the ventilation system could be used as an enhancement to the existing structural arrangements or used as an alternative fire safety mitigation measure. The Analysis document, however, regards the Reactor Building as a special case and does not give sufficient detail to assess the effectiveness of the Containment Sweeping and Blowdown Ventilation System in keeping the staircases free from smoke.

Although the Analysis document contained relevant information, specific detail for the Reactor building was not included and consequently I raised RQ-UKHPR1000-1266 to establish calculated staircase over-pressures in BRX. The subsequent full response broadly demonstrated compliance with relevant good practice and fully closed out the query.

57. RQ-UKHPR1000-1266. Ventilation Analysis – Reactor Building, (Ref. 28). This RQ was issued because the document Analysis of Firefighting Shafts and Staircases Pressurization Systems - Rev A, (Ref. 8) gave insufficient information about the pressures and air flow rates produced by the ventilation system in BRX. The RQ requested that the results of the Ventilation Analysis were reviewed to assess the impact on the protection that pressurisation gives to vital means of escape routes in the Reactor Building. Additionally, details were requested of the status of staircase doors, expected airflow rates, and static pressures to demonstrate that the high capacity ventilation subsystem would support the fire engineering claims that staircases are adequately protected from smoke ingress. The full response to RQ-UKHPR1000-1266 confirmed results of calculations that the static overpressure in the staircases is in the order of 45Pa, meeting the relevant sections of BS EN 12101-6:2005, (Ref. 30), for means of escape. The RP's response adequately resolves issues raised by the RQ and summarises fire engineering justification which takes into consideration; -

- Staircases are within fire protected shafts, fitted with fire resisting doors.
- Fire loads in BRX are strictly limited and clearly identified.
- Cables are rated as low fire spread and where loads are higher, the cables are wrapped.

- Fixed firefighting installations protect equipment containing oil, dependent on flash point.
- Interconnected floor gratings permit smoke to collect under roof and keep the smoke layer higher than 2.6m. Effectively the large compartment size can act as a smoke reservoir.
- Evacuation is calculated to be less than 10 minutes.

58. Confirmation of the level of static overpressure in the staircases, which meets the recommendations of BS EN 12101-6:2005, (Ref. 30), combined with existing fire protection arrangements, effectively demonstrates risks are reduced ALARP and I am satisfied to close out RQ-UKHPR1000-1266.

59. The Reactor Building Gap Management Report, Rev B, (Ref. 13), led to a number of RQs and the ventilation study, which was an additional document submission, before finally providing evidence that risks were adequately assessed. The updated Gap Management Report for BRX, supported by the complimentary Fire Safety Strategy documents, contains an improved assessment of risks and enhanced fire engineering. Although several gaps for the BRX were resolved by the RQs arising from earlier submissions, revision B of the Gap Report describes the management of the remaining departures from relevant good practice. The Gap Management Report identifies 28 residual Gaps from BS 9999 (Ref. 5), which are categorised into six groups of similar type for fire engineering assessment. The fire risk profile, categorised by BS 9999 (Ref. 5), is A3 due to potential fast fire growth rate.

60. <u>Extended escape distances</u>

Gaps 1-11. Eleven rooms were identified which have a single direction of escape exceeding BS 9999 (Ref. 5), recommendations with extensions ranging from 4m to over 66m. This departure from compliance with relevant good practice applies to rooms; -

BRA1701ZRM, BRA1703ZRM, BRA1705ZRM BRA1706ZRM, BRA1707ZRM, BRA1708ZRM, BRA1709ZRM, BRA1711ZRM, BRA1712ZRM, BRA1713ZRM, and BRA1714ZRM.

Gap 4, relating to room BRA1706ZRM, had the second greatest extended escape distance and was selected as a bounding case for assessment. The room with the longest distance was reviewed as Gap 26 due to it also being an inner-inner room.

The Fire Safety Strategy describes that the existing design is maintained after consideration of the following factors which mitigate the increase in escape time caused by the extended distance to a place of relative safety: -

- Controlled access to these rooms with a minimal frequency and duration of occupancy.
- The Auxiliary staircase provides an alternative direction for escape and is a protected escape route from the upper levels to ground floor.
- Escape distance to the Auxiliary staircase is significantly less than the distance to main staircase.
- Fire load is minimal on the route to the staircases.
- Fixed firefighting installation in adjoining compartments containing a high fire load.
- Automatic fire detection in access rooms and escape routes.
- High ceiling provides a reservoir which keeps the escape route clear of smoke and hot gases for a longer period of time than standard height ceilings giving people greater opportunity to escape safely.

- High voltage cables are wrapped.

I am satisfied that the RP's fire engineering assessment adequately demonstrates the existing arrangements reduce risks ALARP and suitable mitigation is in place.

61. Gaps 12 - 14. Compartments BRA2601ZRM, BRA3101ZRM, and BRM3102ZRM are rooms which have alternative directions of escape, but the travel distance exceeds BS 9999 (Ref. 5) recommendations, by less than 7m. The Gap Report describes the existing design is maintained based upon mitigation provided by the following factors: -

- Very limited fire load.
- Limited occupancy with strict access control.
- Compartment 'Risk Profile' assessed as A2 due to a medium fire growth rate and therefore compliant with design guidance for fire safety after taking into account enhanced automatic fire detection and ceiling height.

I am satisfied that the RP's fire engineering assessment demonstrates the existing arrangements reduce risks ALARP and that adequate mitigation is in place.

62. <u>Inner rooms</u>

Gaps 15 - 17. Dead-end compartments BRA3101ZRM, BRA3102ZRM, and BRA3103ZRM, are inner rooms described in the Gap Report as rooms that depart from BS 9999, (Ref. 5), which have an escape distance through the access rooms exceeding 18m. The RP's fire engineering assessment determined that the existing design is maintained because risks are demonstrated to be reduced ALARP, based upon the following factors: -

- Limited occupancy with strict management control.
- Access room is provided with a fixed firefighting installation to effectively control fire growth rate.
- Compartment 'Risk Profile' assessed as A2 due to a medium fire growth rate and therefore compliant with BS 9999 (Ref. 5), after taking into account enhanced automatic fire detection and ceiling height.

I am satisfied that these three gaps are discounted, following a review by the RP which demonstrates the existing fire protection arrangements comply with BS 9999 (Ref. 5), recommendations.

63. <u>Firefighting lobby</u>

Gaps 18 – 25. The following compartments open directly into one of the two staircase enclosures,

BRA1791ZRM, BRA2194ZRM, BRA2691ZRM, BRA2694ZRM, BRA3191ZRM, BRA3194ZRM, BRA3791ZRM, and BRA4291ZRM.

Relevant good practice for a building of this size recommends that firefighting shafts are protected by a lobby containing firefighting water outlets. Lobbies are not available throughout the Reactor Building but alternative mitigation is provided by a pressurisation system described in the full response to RQ-UKHPR1000-1266, (Ref. 28). In the original design of UK HPR1000 fire hoses are located outside of the shafts and in circulation areas of the individual floor plates. The RP's review of firefighting expectations in BRX takes into account; restricted combustible loads; high standard of structural protection, and; availability of areas to prepare firefighting equipment.

I am satisfied that the RP's benchmarking of firefighting provisions against BS 9999 (Ref. 5), demonstrates that the existing arrangements, with fire main outlets located within staircase enclosure are adequate.

64. Specific Case – Inner rooms

Gap 26. Dead-end compartment BRA1705ZRM is an inner room that does not comply with BS 9999 (Ref. 5) recommendations due to the arrangement of multiple access rooms. Additionally, this compartment is the subject of Gap 3 regarding extended escape distance to a place of relative safety. Following a fire engineering assessment by the RP, the existing design is maintained because risks are demonstrated to be reduced ALARP, based upon the following factors: -

- Minimal frequency and duration of occupancy.
- Restricted access with strict management control.
- Enhanced coverage of automatic fire detection.

Other significant factors not claimed in the Gap Report include the high ceilings and small size of the access compartments. Taking all mitigation into account, I am satisfied that the existing arrangements are ALARP.

65. Specific case - Structural Fire Resistance

Gap 27. Good practice for fire safety design in a building of this size, BS 9999 (Ref. 5), recommends a fire resisting compartment floor to separate the basement levels. The original design of the floor of annular space at +1.2m did not meet this standard due to the presence of an equipment access hatch. Following a fire engineering review by the RP, a fire resisting plate is now provided. This modification, as described in The Reactor Building Gap Management Report, Rev B, (Ref. 13), removes the gap and complies with the expectations of BS 9999 (Ref. 5).

66. Specific case - Fire Main Outlets

Gap 28. BS 9999 (Ref. 5) recommends wet or dry rising fire water mains are provided in a building with a firefighting shaft. The gap arises due to the original design containing fire hoses. Following a fire engineering review by the RP, the design is modified to include a wet riser inside the firefighting shaft that is fitted with pressure reducing valves to avoid excess pressure. This modification, recorded in the 'ALARP Demonstration Report', (Ref. 23) removes the gap and complies with relevant good practice.

The resolution of this gap applies not only to the Reactor Building but to all other facilities on the nuclear island which will contain wet risers for firefighting water.

4.2.2 Strengths

67. The Reactor Building was the first facility subject to my Conventional Fire Safety assessment during the GDA process and it was selected due to the likelihood of presenting the greatest challenge to structural expectations for life safety. Over the course of GDA, issues relating to the application of fire safety principles were resolved. Updated documents and the responses to RQs described strengthened fire engineering arguments, resulting in more robust, integrated, and balanced claims that demonstrate risks are reduced ALARP.

4.2.3 Outcomes

68. Fire safety arrangements within the Reactor Building do not completely conform to expectations for traditional buildings. However, the RP has demonstrated that alternative fire engineered methods provide an equally effective level of fire safety.

4.2.4 Conclusion

69. Based on the outcome of my Conventional Fire Safety assessment of the Reactor Building, I have concluded that the formal submissions and full responses to RQs indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

4.3 Safeguard Building Fire Safety Design Assessment.

4.3.1 Assessment

70. My assessment of the Safeguard building refers to BSA, BSB and BSC; collectively these facilities are referenced BSX. The buildings contain the Main Control Room (MCR) and house the systems performing the safety function to support the reactor. The facility comprises three completely independent sub buildings designed as separate fire compartments. Each of the sub buildings are divided into Controlled Areas and Supervised Areas with limited access between the different radiological zones and other buildings on the nuclear island. The facilities contain 9 floor levels from -9.6m to +26.3m. For each sub building, two escape staircases are provided: one for the Supervised area and one for the Controlled area. Fire load in BSX consists mainly of lubricating oil and insulation on electrical cables and devices. During normal power operation personnel occupancy is expected to be about 10 in the Main Control Room with 30 people elsewhere in the building and up to 150 during outage. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout the facility and the fire risk profile, categorised by BS 9999 (Ref. 5), is A3 due to potential fast fire growth rate.

71. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety assessment of the Safeguard Building. Departures from this guidance are also recorded as a gap in the document submissions by the RP. I assessed each gap to ensure suitable mitigation is in place and risks are adequately controlled.

72. Detailed assessment of the Safeguard Building started in Step 3 of the GDA process when the Requesting Party submitted ‘Gap Management Report for Safeguard Building - Rev A (Ref. 31). I reviewed the fire engineering described in this document and presented my observations at a fire safety technical engagement. In response to issues raised, the RP advised that an update to the original document was already in development which addressed several of my observations. The updated document contained enhanced fire engineering which superseded this initial Gap Report.

73. Revision B of the Gap Management Report for Safeguard Building, (Ref. 32), submitted in August 2019, superseded the initial Gap Report, and presented improved fire engineering detail. Extended travel distances in a single direction were identified as the most common departure from relevant good practice in fire safety design. The RP continued to develop improvements to means of escape and resolve escape distances after the formal submission of the Gap Management Report. This continuing fire safety work resulted in the addition of a new staircase that discharges directly to open air at ground floor level. The new fire escape

staircase improves safety by removing the dead-end conditions and resolving the extended escape distances. Subsequently, a further update to the Safeguard Building Gap Management Report to Revision C, (Ref. 17), confirmed the structural alterations that achieve improvements to means of escape and satisfactorily closes the majority of gaps. However, outstanding fire engineering issues contained in revision B of the Gap Management Report for Safeguard Building, (Ref. 32), regarding fire separation of corridors on escape routes and the absence of firefighting lifts, led to two RQs described in the paragraphs below.

74. RQ-UKHPR1000-0445: Fire Separation of Corridors on Escape Routes, (Ref. 28). This RQ asked for an explanation of measures to separate alternative escape routes within the Safeguard Building, with particular emphasis on the lack of sub-division in corridors. The absence of this information in the Gap Management Report was resolved later with further information contained in the submission of Safeguard Buildings Fire Safety Strategy Rev. A, (Ref. 16). The Strategy document confirmed arrangements for achieving fire separation of corridors on escape routes by adding fire resisting doors which met BS 9999 (Ref. 5) recommendations. This information confirms compliance with relevant good practice and closes out the RQ. The exact location for the new doors in the corridor is a matter to be addressed as part of normal business during the development of the site-specific fire risk assessment, as informed by the Safeguard Buildings Fire Strategy Document.

75. RQ-UKHPR1000-0446: Absence of Firefighting Lifts, (Ref. 28).
The original submission did not include adequate provision of firefighting lifts expected by fire safety design guidance for a traditional building of this size. Actions to resolve the issue, proposed in the full response to the RQ, were closed out by submission of Gap Management Report for Safeguard Buildings – revision C, (Ref. 17), which confirmed that all three lifts in the Safeguard Building are upgraded to fire-fighting lifts. The improvement meets the recommendations for lifts as contained within BS 9999 (Ref. 5). The design modification is confirmed in the ‘ALARP Demonstration Report for Conventional Fire Safety’, (Ref 23).

76. Safeguard Building Fire Safety Strategy - Rev A, (Ref. 16). The Strategy submitted in November 2019 proposed evidence that the building design of UK HPR1000 can achieve compliance with GB law by demonstrating risks from fire are fully assessed and adequately controlled. The document describes conventional fire safety arrangements and also details the enhanced measures that support the claims and justifications contained within the ‘Gap Management Report’.

77. I assessed that when read together, the Fire Safety Strategy, revision A, (Ref. 16) and the Gap Management Report - revision B for the Safeguard Building, (Ref. 32), did not contain sufficient detail to demonstrate adequate arrangements were in place to protect staff in the Main Control Room. Typically, in a reactor control room, staff are not expected to immediately evacuate in the event of a fire involving other parts of the building because the design enables people to safely remain in place. However, details of enhanced fire protection arrangements to enable control room staff to remain in position was not evident in the Strategy document.

78. I raised RQ-UKHPR1000-0532-Main Control Room Fire Protection & Evacuation Arrangements, (Ref. 28), to gain further information supporting the fire evacuation arrangements for staff in the control room. The full response to the RQ did not fully resolve my concern, leading to two subsequent RQs: -

RQ-UKHPR1000-0620: Main Control Room, Fire Engineering, (Ref. 28), and RQ-UKHPR1000-0621: Main Control Room, Alternative Directions for Escape, (Ref. 28).

79. Close out of this line of enquiry and compliance with BS 9999 (Ref. 5) recommendations was finally achieved after confirmation that alternative directions of escape are available from both the Main Control Room and the Remote Shut Down Station. These improvements were achieved by designating new emergency routes through existing adjoining rooms and providing fire resisting doors in the corridors; structural modifications are not necessary. The full responses to the three RQs associated with the fire protection strategy for main control room staff, are described in more detail below.

80. RQ-UKHPR1000-0532: Main Control Room Fire Protection & Evacuation Arrangements, (Ref. 28). The RQ raised in November 2019, requested details of the evacuation arrangements from the Main Control Room and Remote Shutdown Station in the Safeguard building with emphasis on the enhanced fire protection arrangements for the means of escape. Confirmation was requested that the risk of fire and smoke spread was fully assessed and adequately controlled, to permit the continued safe occupation of the Main Control Room or Remote Shutdown Station during a fire elsewhere in the Safeguard building. I assessed that the full response to RQ-HPR1000-0532, did not adequately address means of escape and consequently I issued two further RQs;

RQ-UKHPR1000-0620 – Main Control Room, Fire Engineering, (Ref. 28)
RQ-UKHPR1000-0621 – Main Control Room, Alternative Directions for Escape (Ref. 28).

81. Close out, and compliance with BS 9999 (Ref. 5) recommendations for the evacuation arrangements from the Main Control Room and Remote Shutdown station, originally raised in RQ-UKHPR1000-0532, was finally achieved on submission of the full responses to two subsequent RQs. These follow-on RQs described how alternative, fire separated escape routes are available from both the Main Control Room and the Remote Shutdown Station without any structural alterations being necessary.

82. RQ-UKHPR1000-0620: Main Control Room, Fire Engineering. (Ref. 28). Although BSX provides adequate fire protection when a conventional evacuation strategy is in place, the response to a previous RQ-UKHPR1000-532, did not contain sufficient fire engineering information to demonstrate that staff could safely remain in position, during a fire elsewhere in the Safeguard Building.

83. RQ-UKHPR1000-620, requested an explanation of fire protection throughout the complete escape route from the Main Control Room and Remote Shutdown station to places of relative safety. The RQ also required information to demonstrate that the arrangements in case of a fire were adequate and residual risks controlled and reduced ALARP.

84. The full response identified that alternative directions of escape could be made available from the Remote Shutdown Station by designating a new escape route through existing adjacent cabinet rooms which gave an alternative escape route to the corridor. No structural alterations are required to accomplish the improvements. Separation of the alternative directions of escape is achieved by locating fire resisting doors in the corridor immediately outside the Remote Shutdown Station. Confirmation of corridor fire separation in the Safeguard Building Fire Safety Strategy - Rev A, (Ref. 16), fully closes out RQ-UKHPR1000-0620 by providing alternative fire separated escape routes through the addition of suitably positioned fire resisting doors in the access corridor. The arrangement achieves compliance with BS 9999 (Ref. 5) recommendations for means of escape.

85. RQ-UKHPR1000-0621: Main Control Room, Alternative Directions for Escape. (Ref. 28).
This RQ also arises due to an earlier query not fully addressing the need for enhanced fire protection permitting staff to safely remain in the Main Control Room and Remote Shutdown Station during a fire elsewhere in BSX.

86. RQ-UKHPR1000-0621, requested further assessment of the design against relevant good practice including the provision of alternative directions of escape. The full response to the RQ resolves means of escape issues from the Main Control Room by proposing a new escape route through adjacent rooms combined with sub-division of the escape corridor to provide an alternative route to protected staircases. No structural alterations are required to achieve these improvements and the provision of corridor separation by fire resisting doors is detailed in the Safeguard Building Fire Safety Strategy - Rev A, (Ref. 16). Confirmation of these alternative and fire separated escape routes satisfactorily closes out the RQ by achieving compliance with BS 9999 (Ref. 5) recommendations for means of escape.

87. Safeguard Building Gap Management Report - Rev C. (Ref. 17). Assessed in December 2019. The purpose of this document is to record every aspect of the building design which departs from the recommendations within BS 9999 (Ref. 5), and to apply a fire engineering process that results in measures to reduce the risk gap or demonstrate that the existing fire safety arrangements are adequate, and risks are already reduced ALARP.

88. This updated Safeguard Building Gap Management Report, revision C, (Ref. 17), consolidates previous work by the RP to improve means of escape and confirms the structural alterations to the original design that adds a new escape staircase which discharges directly to open air. The document was included in my Step 4 GDA Assessment Plan as an item requiring follow-up because the submission date was rescheduled to permit adequate time for assessment of security and radiological protection implications arising from the addition of the new fire escape staircase. This new escape route resolves the initial challenges arising from extended escape distances described in Gaps 1-9 and unsatisfactory inner room conditions described in Gaps 22-27, below.

89. Although several gaps for the BSX were resolved by the RQs arising from earlier submissions, this updated document describes the management of the remaining departures from relevant good practice. The Safeguard Building Gap Management Report - Rev C, (Ref. 17) identified 31 residual Gaps from British Standard 9999 (Ref. 5), which are categorised into six groups of similar type for fire engineering assessment. The fire risk profile, categorised by BS 9999 (Ref. 5), is A3 due to a potential fast fire growth rate.

90. <u>Extended escape distances.</u>

Gaps 1-9. Nine rooms were identified which had a single direction of escape exceeding BS 9999 (Ref. 5), escape distance recommendations by up to 30m. Following a review by the RP, means of escape is fully resolved through structural alterations which include addition of a new spiral staircase that discharges directly to open air at ground floor level. Confirmation of the design modification is given in the ‘ALARP Demonstration Report for Conventional Fire Safety’, (Ref 23). This category 3 design modification, TCN Code GHTCN000095, number M11 brings the following compartments into compliance with the escape distance recommendations of BS 9999 (Ref. 5);

BSC1021ZRM, BSC1022ZRM, BSC1023ZRM, BSC1024ZRM, BSC1521ZRM, BSC1522ZRM, BSC1524ZRM, BSC2022ZRM and BSC2023.

91. Gaps 10-12. Compartments BNX2022ZRM, BNX2023ZRM and BNX2024ZRM had a single direction of escape that exceed BS 9999 (Ref. 5), recommendations for escape distance by over 9m. Following a fire engineering assessment by the RP, modifications add a new fire resisting corridor giving direct access to the escape staircase from each compartment. This design change removes the extended escape distance and achieves compliance with relevant good practice, BS 9999 (Ref. 5) recommendations for means of escape. The alterations to the design, described in the Gap Management Report, are confirmed within Category 3 modification M12, TCN Code GHTCN000093, 'Modification of evacuation route in BSC'.

92. Gaps 13-21. The existing design is maintained for the following compartments which depart from good practice in fire safety design due to extended travel distances for rooms which have alternative directions of escape;

BSA1026ZRM, BSA1027ZRM, BSB1026ZRM, BSB1027ZRM, BSB1527ZRM, BSA2025ZRM, BSB2423ZRE, BSB3702ZRM and BSB4018ZRX.

The RP's assessment of the existing fire protection arrangements adequately demonstrates risks are suitably controlled and reduced ALARP. The Fire Safety Strategy details consideration of the following factors which mitigate the increase in escape time caused by the extended distance to a place of relative safety: -

- Restricted fire load with low rate of spread of flame along the escape route.
- Fixed firefighting installation.
- Automatic fire detection in access rooms.
- High ceiling provides a reservoir which keeps the escape route clear of smoke and hot gases for a longer period of time than standard height ceilings, giving people greater opportunity to escape safely.
- High voltage cables are wrapped.
- Restricted occupancy.
- High standards of management control.

I am satisfied that the RP's fire engineering has fully assessed the risks, given appropriate significance to the effectiveness of the mitigation, and that the arrangements provide adequate protection for people from the danger of fire.

93. <u>Inner-inner rooms</u>

Gaps 22-27. Compartments, BSC1021ZRM, BSC1022ZRM, BSC1521ZRM, BSC2022ZRM, BSB20231ZRM and BSB2024ZRM were inner rooms that in the original design did not meet expectations of good practice because of the need to escape through multiple access rooms. Following a fire engineering assessment by the RP, the inner room conditions for these compartments is resolved by the provision of a new spiral staircase that discharges to open air at ground floor level. The design modification improves means of escape from these six compartments, removes the gap and meets the expectations of BS 9999 (Ref. 5). The design change to include the additional staircase is referenced as modification M11, TCN Code GHTCN000095 and is confirmed in the 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23).

94. <u>Fire mains</u>

Gap 28. BS 9999 (Ref. 5) recommends wet or dry rising firefighting mains due to the height of the building. The PR has resolved the gap by changing the original design to incorporate wet rising fire mains with outlets located within firefighting shafts. This modification provides adequate facilities for firefighters. This design modification has been applied across all UK HPR1000 buildings, to meet GB expectations for firefighting and is confirmed in the ALARP Demonstration Report for Conventional Fire Safety, (Ref 23).

95. Firefighting lifts

Gap 29. BS 9999 (Ref. 5) recommends firefighting lifts for a building of this size. Following the RP's review of the original design, the Fire Safety Strategy describes a modification to the equipment specification that ensures existing lifts are upgraded to meet the firefighting standard. This alteration complies with the expectations of BS EN81-72 (Ref. 33) and removes the gap. The category 3 design modification, TCN Code GHTCN000180, number M79, is confirmed in the 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23).

96. Firefighting shaft protection

Gap 30. BS EN 12101-6, (Ref. 30), specifications for air flow in firefighting shafts when access doors are open, is not fully met. Submission of the document, Analysis of Firefighting Shafts and Staircases Pressurization Systems - Rev A (Ref. 8), demonstrates that the existing arrangements reduce risks ALARP for Controlled Areas by confirming adequate arrangements to maintain static overpressures and therefore closes this gap for GDA. The document confirms existing ventilation conditions enhance the resilience of the escape routes by mitigating smoke ingress from a fire in adjacent compartments. I am satisfied that the departure from guidance relating to air flow through open staircase doors will not impair means of escape or significantly affect the safe use of the staircase during firefighting operations. The work undertaken during the study of pressurisation systems also identified potential enhancements to the ventilation system, that can be incorporated during site specific stages and used as alternative mitigation in place of other fire protection measures. I consider however, that the existing arrangements using passive structural fire protection is more reliable and resilient, and fully satisfies my expectations for GDA.

97. Staircase discharge arrangements

Gap 31. Fire protection for staircase BSC2002ZRX originally did not meet BS 9999 (Ref. 5), recommendations because the staircase discharged into an unprotected compartment. Design modifications are confirmed in the Gap Management Report for Safeguard Building – Rev C, (Ref. 17), which include the formation of a new fire protected lobby in compartment BSC2024ZRM and relocation of electrical equipment out of the area. This is recorded as a category 3 modification, TCN Code GHTCN000093, number M12. These alterations remove the gap and bring the staircase arrangements into compliance with relevant good practice, BS 9999 (Ref. 5).

98. In summary, the Gap Management Report for Safeguard Building – Rev C, (Ref. 17), provides a suitable and sufficient assessment of risk from fire. The modifications identified in the Gap Report bring the building into compliance with relevant good practice, and adequate mitigation and fire engineering justification is given for residual departures from BS 9999 (Ref. 5), to demonstrate risk is reduced ALARP.

4.3.2 Strengths

99. The RP implemented a significant number of modifications within the Safeguard Buildings that reduce the risk to people from the danger of fire. The addition of the new escape staircase is a notable example of improvements that provide real safety

benefit across several floor levels by reducing escape distances and removing dangerous dead-end conditions arising from multiple inner room layouts.

The number and scale of modifications demonstrates the RP's commitment to reduce risk gaps and drive safety.

4.3.3 Outcomes

100. The modifications introduced by the RP have resulted in a facility that is compliant with the recommendations for relevant good practice in building design for fire safety and the few remaining areas which depart from guidance are fully assessed and risks reduced ALARP.

4.3.4 Conclusion

101. Based on the outcome of my conventional fire safety assessment of the Safeguard Buildings, I have concluded that the formal submissions and full responses to Regulatory Queries indicate that the generic design will satisfy GB legal requirements for the protection of people from the danger of fire.

102. Arrangements within the Safeguard Building conform to British Standard 9999 (Ref. 5), the benchmark for relevant good practice in the fire safety design of buildings, and adequate fire engineered mitigation is in place for the small number of areas which depart from compliance with this guidance.

4.4 Fuel Building Fire Safety Design Assessment.

4.4.1 Assessment

103. My assessment of the Fuel building refers to BFX. The building consists of three safety divisions over 9 floors from -9.6m to +26m. The facility is mainly used for fuel handling and storage, the spent fuel pool, fuel reception compartment, new fuel assembly storage room, fuel operational hall and cranes. An escape staircase is provided for each division; two of which are constructed within firefighting shafts. The main types of fire load in BFX are lubricating oil, charcoal, and multilayer electrical cables in the cable shafts as well as in several pipe rooms. During power operation, operators are not permanently based in the building but will enter BFX for regular inspection; the maximum number of people is expected to be about 20. During outage, the maximum number of people will increase to about 100. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout the facility and the fire risk profile assessed against BS 9999 (Ref. 5), is considered A3 due to potential fast fire growth rate.

104. I used BS 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety assessment of the Fuel Building. Departures from this guidance are also recorded in the document submissions by the RP as a gap. I assessed each gap to ensure suitable mitigation is in place and risks are adequately controlled.

105. Detailed assessment of BFX started in Step 3 of the GDA process when the Requesting Party submitted Gap Management Report for Fuel Building – Rev. A, (Ref. 34). I reviewed the fire engineering contained in this document in June 2019 and subsequently raised two RQs described in the paragraphs below. RQ-UKHPR1000-0351, (Ref. 28), concerned means of escape and RQ-UKHPR1000-0352, (Ref. 28), related to delay in fire evacuation. The full responses to the two RQs provided additional information which effectively resolved my queries. The Gap Management Report – revision A, (Ref. 34), was superseded by a later update which incorporated the improvements described in the full responses to the two

RQs. Due to building design modifications and changes in fire protection arrangements occurring since the submission of the initial Gap Report, fire engineering details in the initial document are no longer relevant to UK HPR1000 and consequently are not included in my Conventional Fire Safety Assessment Report but a description of the RQs is given below for context.

106. RQ-UKHPR1000-0351. Means of Escape from the Fuel Building, (Ref. 28). This RQ asked for details of the methodology used by the RP to ensure all significant departures from relevant good practice in fire safety design of buildings are correctly identified. Additionally, the RQ also challenged the use of the 'principal of progressive horizontal escape' when assessing means of escape from dead-end locations. The full response to the RQ adequately described how each compartment is assessed against a checklist derived from BS 9999 (Ref. 5), to ensure all relevant departures from good practice are identified. The response also confirmed that escape from dead-end compartments would be re-assessed. The RQ was finally closed out with submission of Revision B of the Gap Management Report for BFX, (Ref. 15), which reviewed the approach taken in the assessment of means of escape for dead-end conditions and described structural alterations that improved fire protection by forming an alternative escape route and demonstrating that residual risks are reduced ALARP. Details regarding the fire safety improvements are reviewed below.

107. RQ-UKHPR1000-0352. Evacuation Delay from Fuel Building, (Ref. 28). I requested additional information to clarify the fire evacuation strategy described in revision A of the Gap Management Report for the Fuel Building, (Ref. 34). Whilst introducing a predetermined investigation period before raising a full building fire warning alarm is an accepted practice, I challenged the use of this approach in a building where there are examples of extended escape distances and unsatisfactory inner room conditions. The full response to the RQ satisfactorily explained that activation of a fire detector will result in immediate local alarm, warning people to evacuate from relevant compartments without delay. Elsewhere in the building, after elapse of a pre-set investigation time, a full facility fire evacuation warning is sounded. Confirmation of the arrangements described in the full response are detailed in the Fuel Building Fire Strategy document, revision A (Ref. 14). Although this issue is satisfactorily closed out for GDA, details of the fire compartments comprising the definition of 'local area' is a site-specific issue to be addressed as part of normal regulatory business.

108. Fuel Building Fire Strategy - Rev A. (Ref. 14). This document defines the fire protection arrangements and how the building and its occupants are expected to react, should a fire occur. The Fire Strategy describes conventional fire precautions and also the enhanced measures that support the claims within the companion 'Gap Management Report' that risks are reduced ALARP. Read in combination, the Fire Strategy, and the Gap Management Report, revision B (Ref 15), provide the full suite of conventional fire safety measures in BFX. I reviewed the Strategy for compliance with GB legislation, primarily the Regulatory Reform (Fire Safety) Order 2005 (Ref. 9) and the selection of relevant good practice for fire safety, including fire detection and warning and management arrangements. I assessed the Strategy in combination with the relevant Gap Report, to ensure the fire safety case is adequate. The Strategy document describes suitable arrangements to satisfy legal requirements and meet GB expectations for industry good practice in fire safety design.

109. Gap Management Report for Fuel Building, Rev B. (Ref. 15). Reviewed in November 2019, the purpose of this document is to record every aspect of the building design which departs from the recommendations within BS 9999 (Ref. 5), and to apply a fire engineering process that results in measures to reduce the risk

gap or demonstrate that the existing fire safety arrangements are adequate and risks are already reduced ALARP.

The updated Gap Report incorporates the structural modifications to address single direction of escape issues proposed in RQ-UKHPR1000-0351-Means of Escape Fuel Building (Ref. 28). Although several gaps for the BFX were resolved by the RQs arising from earlier submissions, this updated document describes the management of the remaining departures from relevant good practice. The Gap Management Report identifies 15 residual Gaps from British Standard 9999 (Ref. 5), which are categorised into five groups of similar type for fire engineering assessment.

110. Extended escape distances

Gaps 1 – 3. Compartments BFX2458ZRM, BFX2958ZRM and BFX3358ZRM have a single direction of escape that exceeds BS 9999 (Ref. 5) recommendations for travel distance by less than 5m. The RP determined that the existing design was ALARP following a fire engineering assessment which considered: -

- Very limited fire load with low rate of spread of flame along the escape route.
- Fixed firefighting installation mitigates high fire load in compartment BFX3358ZRM.
- Automatic fire detection in access rooms.
- Extended escape distance results in only a slight increase of escape time.

I judged that the RP's assessment is satisfactory, and the escape distances are adequately justified.

111. Provision of fire water outlets

Gaps 4 & 5. The arrangement of firefighting water outlets in BFX, varies from BS 9999 (Ref. 5). The RP decided to retain the initial design following a risk assessment of anticipated firefighting operations which demonstrates existing arrangements are satisfactory. I am satisfied that the minor increase in number of fire hose lengths to reach a small number of rooms is deemed acceptable and risk to firefighters is ALARP, based upon the limited fire load, high standards of structural fire protection and small compartment size.

112. Unsatisfactory Inner-inner room conditions

Gaps 6 – 13. The following dead-end compartments were inner rooms which did not meet relevant good practice for fire safety design due to the number of access rooms;

BFX1012ZRM, BFX1013ZRM, BFX1052ZRM, BFX1053ZRM, BFX1552ZRM, BFX2412ZRM, BFX4245ZRM, BFX4259ZRM.

The Strategy describes how means of escape is evaluated and resolved using BFX1013ZRM and BFX2412ZRM as the bounding cases. I am satisfied with the RP's fire engineering assessment that a new vertical ladder to the floor above the compartments provides an alternative escape route from the area and addresses escape issues arising from the presence of high fire loads in access rooms. I consider the use of a ladder acceptable for the restricted frequency and limited occupancy of these rooms. The design alteration is considered a category 3 modification TCN Code GHTCN000114, number M29. The modification removes the gap and complies with the recommendations of BS 9999 (Ref. 5).

113. Absence of firefighting lifts.

Gap 14. Relevant good practice for building design recommends the provision of firefighting lifts in a traditional structure of this size. Following the RP's fire safety assessment, the Gap Report confirms that the existing lifts in BFX will be upgraded to meet the firefighting standard recommended in BS 9999 (Ref. 5). Confirmation of the design modification is given in the 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23) and is recorded as a category 3 modification, number M79, 'Modification of Fire-fighting Lifts in Safeguard Buildings', TCN Code GHTCN000180.

114. Firefighting facilities

Gap 15. Relevant good practice recommends the installation of wet or dry risers in a building of this height. Following a review of firefighting facilities, by the RP, the Gap Report for the Fuel Building – Rev B. (Ref. 15) confirms that the internal firefighting water supply arrangements meets the recommendations of BS 9999 (Ref. 5), by the provision of wet risers. This design modification meets GB expectations for firefighting and has been applied across all generic design UK HPR1000 buildings. The alterations are confirmed in the 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23).

115. In summary, the Gap Management Report for Fuel Building – Rev B, (Ref. 15), provides a suitable and sufficient assessment of risk from fire. The modifications identified in the Gap Report result in a building which complies with relevant good practice and adequate mitigation is given to the remaining small number of departures from BS 9999 (Ref. 5), which demonstrate residual risk is reduced ALARP.

4.4.2 Strengths

116. The RP has implemented a significant number of modifications within the Fuel Building that reduces the risk to people from the danger of fire. The initial design of the Fuel building did not meet the expectations within British Standard 9999 (Ref. 5), regarding firefighting lifts. However, subsequent optioneering assessed not only the Fuel Building but also took into account the impact of any decision on the Reactor building, which does not have a lift. The wider consideration of other buildings on the nuclear island was a significant factor in the decision to provide the enhanced firefighting lifts in the Fuel Building. The overall result is an example of good practice in controlling risk in an integrated manner.

4.4.3 Outcomes

117. The modifications introduced by the RP result in a facility that is compliant with the recommendations of BS 9999 (Ref. 5). The few remaining areas which depart from guidance are fully assessed, and the RP has adequately demonstrated risks are controlled and reduced ALARP.

4.4.4 Conclusion

118. Based on the outcome of my conventional fire safety assessment of the Fuel Building, I have concluded that the formal submissions and full responses to Regulatory Queries, indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

119. Fire Safety arrangements within the Fuel Building conform to relevant good practice, British Standard 9999 (Ref. 5), and for areas which depart from compliance with this guidance, adequate fire engineered mitigation is in place.

4.5 Nuclear Auxiliary Building Fire Safety Design Assessment.

4.5.1 Assessment

120. My assessment of the Nuclear Auxiliary Building refers to BNX. The building houses systems for normal plant operation and consists of a Controlled Area spanning 10 floors from -10m to +26m, and a Supervised Area with 8 floors from -7m to +20m. There are limited connections between the Controlled Area and Supervised Area. Four escape staircases are provided within the Controlled Area and three escape staircases within the Supervised Area. The building has two final exits at ground floor; however, not all staircases discharge directly to a place of safety. Two firefighting shafts are available: one in the Controlled Area, the other in the Supervised Area. The main fire loads arise due to insulation on electrical cables, electrical cabinets, and lubricating oil. During power operation, the maximum number of people is expected to be about 10. During outage, the maximum number of people could increase to around 100. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout the facility. Generally, the fire risk profile is A2 due to an assessed medium fire growth rate, determined with reference to BS 9999 (Ref. 5), however, certain individual compartments are rated A3 due to fire load characteristics and potential faster fire growth.

121. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety assessment of the Nuclear Auxiliary Building. Departures from this guidance are also recorded in the document submissions by the RP, as a gap. I assessed each gap to ensure suitable mitigation is in place and risks are adequately controlled.

122. Detailed assessment of BNX started in Step 4 of the GDA process with submission of the Fire Safety Strategy for the Nuclear Auxiliary Building – Rev. A, (Ref. 35). I reviewed the fire engineering contained in this initial document in May 2020 and due to departures from building design guidance contained within BS 9999 (Ref. 5), I subsequently issued three RQs to gain further information.

RQ-UKHPR1000-0667 (Ref. 28) concerned staircase discharge arrangements.
RQ-UKHPR1000-0668 (Ref. 28) challenged escape from dead-end conditions.
RQ-UKHPR1000-0669 (Ref. 28) challenged access to firefighting lifts.

The full responses to these RQs proposed measures to resolve the issues through a combination of building design modifications and enhanced fire engineering assessments. Close out of the fire safety queries was achieved on submission of a revised Fire Strategy document which implemented the structural alterations and included additional information to support the risk assessments. The updated document supersedes this initial Fire Strategy. However I have included a description of the relevant RQs to provide context to my assessment.

123. RQ-UKHPR1000-0667. Staircase Discharge Arrangements, (Ref. 28).
The RQ challenged the escape arrangements of five staircases in BNX, which did not comply with relevant good practice because they failed to discharge directly to a place of relative safety. The full response to the RQ identified solutions to improve the escape routes from the staircases by making structural modifications and improving fire protection to achieve compliance with the recommendations of BS 9999 (Ref. 5). Submission of the Fire Safety Strategy for the Nuclear Auxiliary

Building to Revision B (Ref. 18), implemented the proposed design modifications and fully closed out the issues raised in RQ-UKHPR1000-0667. A summary of the measures to adequately resolve staircase fire protection is listed in subsequent paragraphs and described in more detail as gaps 20 – 24 in revision B of the BNX Fire Safety Strategy (Ref. 18).

124. RQ-UKHPR1000-0668. Dead-end Conditions Nuclear Auxiliary Building, (Ref. 28). Room BNX3675ZRM was identified in the initial Fire Strategy document because of its extended distance for escape. However, I took the view that a greater life safety risk was presented by its arrangement as a dead-end inner room condition with multiple access rooms, and consequently means of escape was a higher priority and required further fire engineering review. The full response to the RQ, proposed formation of an alternative escape route from the Supervised Area to the Controlled Area which removed the unsatisfactory multiple access room condition and resolved the extended escape distance. Submission of Revision B of the Fire Safety Strategy (Ref. 18) removes both of these gaps and closes out the RQ by confirming the structural design alteration that satisfactorily resolves means of escape described in the section containing Gaps 9-11.

125. RQ-UKHPR1000-0669. Access to Firefighting Lifts, (Ref. 28).
This RQ arises due to the absence of firefighting lifts in BNX. In a conventional building of this size, BS 9999 (Ref. 5), recommends that dedicated firefighting lifts serve every floor. The RQ challenges the proposal to use the firefighting lifts in buildings adjoining the Nuclear Auxiliary building, which only has access to adjacent buildings at a limited number of floor levels.

126. The full response to RQ-UKHPR1000-669 describes the optioneering undertaken to attempt to provide lift facilities for firefighters that meets the relevant good practice. The RP's review determines that existing arrangements; with firefighting lift access restricted to the highest, lowest, and ground floor level, is adequate. The assessment evaluates the need for; radiological protection, layout issues resulting from dissimilar floor levels in adjoining facilities and limited firefighting expectations due to restricted fire loading in individual compartments and high standards of structural fire protection in the building. I am satisfied that the RP's assessment of facilities for firefighting demonstrates that existing arrangements are adequate because risks to firefighters are reduced ALARP. An update to the original Fire Safety Strategy for the Nuclear Auxiliary Building to Revision B, (Ref. 18), details the improved risk assessment and closes the RQ.

127. Fire Safety Strategy for the Nuclear Auxiliary Building, Revision B, (Ref. 18). The Strategy defines the fire protection arrangements and how BNX and its occupants are expected to react, should a fire occur. The document describes both conventional fire precautions that are applicable to the whole building and the fire engineering undertaken to manage gaps arising from individual fire compartments that depart from compliance with relevant good practice. The Strategy document describes suitable arrangements to satisfy legal requirements and broadly meet GB expectations for industry good practice in fire safety design. Areas which depart from BS 9999 (Ref. 5), are detailed in the paragraph below.

This updated document incorporates the structural modifications proposed in RQ-HPR1000-0667-Staircase Discharge Arrangements, (Ref. 28), and RQ-HPR1000-0668-Dead-end Conditions Nuclear Auxiliary Building (Ref. 28). Although several gaps for the BNX were resolved by the RQs arising from earlier submissions, this updated document describes the management of the remaining departures from relevant good practice. The Strategy document identifies 24 remaining Gaps from British Standard 9999 (Ref. 5), which are categorised into five groups of similar type for fire engineering assessment.

128. Extended escape distances

Gaps 1 & 2. Compartments BNX0934ZRM and BNX0996ZRM have a single direction of escape that exceeds BS 9999 (Ref. 5), recommendations for travel distances by less than 5m. I am satisfied that the fire engineering assessment undertaken by the RP has determined risks are reduced ALARP with the existing design after consideration of the following factors: -

- Very limited fire load with low rate of spread of flame along the escape route.
- Electrical cable trays are wrapped or protected by a sprinkler system. Where cables are wrapped, the standard of fire resistance applied, is the same as the compartment barrier and therefore not evaluated as a combustible load.
- Extended escape distances result in only slight increase in escape time.
- Enhanced coverage of automatic fire detection.
- Strict access-controlled area.

129. Gaps 3-5. Compartments BNX1330ZRM, BNX1331ZRM and BNX2331 had a single direction of escape that exceeded BS 9999 (Ref. 5), recommendations for travel distances by over 7m. The Strategy document describes how means of escape is resolved by making structural alterations that include the provision of an additional escape staircase in BNX1331ZRM. The modifications resolve the escape distance requirements of BS 9999 (Ref. 5), for the three compartments and remove the gap from relevant good practice.

130. Gap 6. Compartment BNX2720ZRM had a single direction of escape that exceeded BS 9999 (Ref. 5), travel distance recommendations by over 7m. Following a fire engineering assessment by the RP, the Strategy describes design modifications involving relocation of existing door from the compartment which reduces the escape distance and achieves compliance with relevant good practice.

131. Gap 7 & 8. Compartments BNX2786ZRM and BNX2788ZRM had a single direction of escape that exceeded BS 9999 (Ref. 5), travel distance recommendations by over 3.5m. The Strategy details the fire engineering assessment resulting in structural alterations that introduces a new exit door in BNX2789ZRM and reduces the escape distance from both compartments. The design modification achieves compliance with BS 9999 (Ref. 5), relevant good practice, and removes the gaps.

132. Gap 9-11. Compartments BNX3675ZRM, BNX3676ZRM and BNX3679ZRM had a single direction to the exit that exceeded BS 9999 (Ref. 5), escape distance recommendations by greater than 18m for the bounding case. The original unsatisfactory dead-end conditions of room BNX3675ZRM was also the subject of RQ-UKHPR1000-0668. Following a fire engineering assessment by the RP, a new escape route is provided using an existing door into the Controlled Area. The door, which is locked under normal conditions, will unlock on operation of the fire alarm system providing a new escape route. These alterations resolve both the extended escape distance for all three compartments and the unsatisfactory inner room conditions for BNX3675ZRM. The modifications remove the gaps from compliance with BS 9999 (Ref. 5), relevant good practice in the design of buildings for fire safety.

133. Inner-inner rooms

Gaps 12-14. Dead-end compartments BFX1013ZRM and BFX2412ZRM, are inner rooms that depart from design guidance for means of escape due to the arrangement of multiple access rooms. I am satisfied that the fire engineering assessment, undertaken by the RP, adequately justifies the decision to maintain the existing design because risks are already reduced ALARP, based upon the following factors: -

- Very limited fire load with low rate of spread of flame along the escape route.
- Electrical cable trays are wrapped or protected by fixed water sprinkler system.
- Automatic fire detection specified to L2 category of BS 5839 (Ref. 26) due to enhanced specification of detector coverage.
- Strict access-controlled area

134. Gap 15. The inner-inner room conditions for compartment BNX0956ZRM originally did not meet expectations of BS 9999 (Ref. 5), because of the access arrangements. Means of escape was resolved by structural alterations requiring construction of a new fire compartment wall. The new structure improves safety by providing two separate alternative directions of escape thereby reducing the number of dead-end access compartments and removes the gap.

135. Gap 16 & 17. BNX2786ZRM and BNX2788ZRM are inner-inner rooms that did not meet expectations of good practice for means of escape due to the layout of access rooms. Following the RP's fire engineering assessment, the inner room conditions are improved by the structural alterations which result in a new exit door from compartment BNX2789ZRM. The modifications remove the gap and bring the compartments into compliance with BS 9999 (Ref. 5).

136. <u>Absence of firefighting lifts and lobbies</u>

Gap 18. The absence of firefighting lifts in the Nuclear Auxiliary building fails to meet recommendations in BS 9999 (Ref. 5), for firefighting facilities in conventional buildings of this size. This issue was the subject of RQ-UKHPR1000-0669, (Ref. 28), which resulted in further study into firefighting expectations for BNX. The subsequent firefighting assessment reviewed the impact of radiological protection requirements and layout issues resulting from dissimilar floor levels in adjacent facilities; both are features which restrict the possibility of sharing firefighting lifts through formation of new interconnections between buildings. Taking into account the limited firefighting expectations necessary in BNX due to the restricted fire loading in individual compartments, and high standards of structural fire protection available in the building, I am satisfied with the findings of the review which demonstrated that access to firefighting lifts in adjoining buildings at levels +16.05m, 0.00m and -10.25m reduces risks to ALARP and provides adequate facilities for firefighters.

137. <u>Firefighting facilities.</u>

Gap 19. Fire hose reels do not meet GB expectations for good practice for the provision of firefighting water outlets. Revision B of the Fire Strategy, for the Nuclear Auxiliary Building, (Ref. 18), changes the original proposal and confirms the installation of a wet rising fire main with landing valve outlets in protected areas, satisfying BS 9999 (Ref. 5), recommendations and removing the gap.

138. <u>Staircase discharge arrangements</u>

BNX staircases described in Gaps 20-24, below, originally failed to meet good practice in design for fire safety because they discharged at access level into an unprotected area. BS 9999 (Ref. 5) recommends that fire protected staircases discharge directly to a place of safety or to a fire protected escape route. This means of escape issue affected five staircases and resulted in issue of RQ-UKHPR1000-0667-Staircase Discharge Arrangements (Ref. 28). The full response to the query identified improvements for all five staircases and the structural arrangements to reduce risk ALARP are included in the Fire Safety Strategy for the Nuclear Auxiliary Building to Revision B. (Ref. 18), and also confirmed in the 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23). This structural redesign is categorised as a level 3 modification TCN Code GHTCN000122, number M33. A summary of the fire engineering assessment for each of the five staircases is given in the next paragraphs. The structural modifications bring the design into compliance with relevant good practice and satisfy GB legal requirements.

139. Gap 20. Escape staircase BNX0901SFA/BNX2001SFA led to an unprotected corridor at access level to the Safeguard Building. Following a fire engineering review, undertaken by the RP during the development of the Fire Safety Strategy, the design was modified by adding a fire resisting wall and doors to form a new pressurised, fire protected lobby. The lobby broadly satisfies BS 9999 (Ref. 5), with a minor departure remaining due to the area of the lobby being slightly larger than recommendations. This residual risk is ALARP and a reasonable expectation on the licensee to ensure the lobby is maintained free from combustible items during normal operation of the power plant.

140. Gap 21. Escape staircase BNX0902SFA/BNX2006SFA led to the unprotected hosting area at access level close to the exit into to the Radioactive Waste Treatment Building. Following a fire engineering review, undertaken during the development of the Fire Safety Strategy by the RP, the building design has been modified to add an additional escape door into the staircase to the Supervised Area which gives direct access into the Radioactive Waste Treatment Building. This additional exit improves means of escape and removes the gap from BS 9999 (Ref. 5), recommendations.

141. Gap 22. Escape staircase BNX0903SFA/BNX2003SFA led to the unprotected anteroom which opens directly into the hosting area at access level. Following a fire engineering review, undertaken during the development of the Fire Safety Strategy by the RP, the building design has been modified to add a fire resisting partition in room BNX2065ZRM which separates the escape route from the hosting area and forms a new exit door giving access directly into the Radioactive Waste Treatment Building. The fire protected escape route and exit improves means of escape and removes the gap from BS 9999 (Ref. 5), recommendations.

142. Gap 23. At discharge level, escape staircase BNX1601SFA/BNX2007SFA originally opens into the Chiller rooms which have a high fire loading. Following a fire engineering review, undertaken during the development of the Fire Safety Strategy by the RP, the building design has been modified to add a fire resisting lobby at access level which gives an escape route into the Radioactive Waste Treatment Building. The fire protected lobby and new exit route improves means of escape and satisfies BS 9999 (Ref. 5), recommendations.

143. Gap 24. Escape staircase BNX2005SFA also originally exited into the Chiller rooms which have a high fire loading. Following a fire engineering review, undertaken during the development of the Fire Safety Strategy by the RP, the building design has been modified by adding a new exit door from the staircase enclosure into the fire resisting lobby at access level of the Controlled Area. This lobby gives direct access to the Safeguard building. The additional exit into the Controlled area improves means of escape and removes the gap from BS 9999 (Ref. 5), recommendations.

144. In my view, the Fire Safety Strategy for the Nuclear Auxiliary Building, Revision B, (Ref. 18), provides a suitable and sufficient assessment of risk from fire. The modifications identified in the Fire Safety Strategy bring the building into compliance

with relevant good practice and adequate mitigation and fire engineering justification is given for residual departures from BS 9999 (Ref. 5), to demonstrate risk is reduced ALARP.

4.5.2 Strengths

145. The RP has modified the design of the Nuclear Auxiliary Building to improve the safety of people from the danger of fire. Structural alterations to enhance fire protection for five staircases and other modifications to remove unsatisfactory dead-end conditions and extended escape distances provides real safety benefit.

The number and scale of modifications demonstrates the RP's commitment to reduce risk gaps and drive safety.

4.5.3 Outcomes

146. The modifications implemented by the RP, has resulted in a facility that is compliant with GB recommendations for relevant good practice in building design for fire safety and the few remaining areas which depart from guidance are fully assessed and the RP has adequately demonstrated risks are controlled and reduced ALARP.

4.5.4 Conclusion

147. Based on the outcome of my Conventional Fire Safety assessment of the Nuclear Auxiliary Building, I have concluded that the formal submissions and full responses to Regulatory Queries, indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

148. Fire Safety arrangements within the Safeguard Building conforms to relevant good practice, British Standard 9999 (Ref. 5), and for areas which depart from compliance with this guidance, adequate fire engineered mitigation is in place.

4.6 Radioactive Waste Treatment Building Fire Safety Design Assessment.

4.6.1 Assessment

149. My assessment of the Radioactive Waste Treatment Building refers to BWX. The building is designed to arrange the reception and treatment facilities for radioactive waste from the operational and maintenance activities in the nuclear island. The facility is effectively divided into a larger Controlled Area and a separate Supervised Area with limited connections between the two areas. Both areas are provided with two escape staircases. There are two fire-fighting shafts, one for the Controlled Area and the other for the Supervised Area; these staircases are pressurised to 45Pa but not provided with fire-fighting lobbies. The building contains 5 floor levels from -10.25m to +10m. Fire load in the Radioactive Waste Treatment Building consists mainly of electrical cables, and control cabinets. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout the facility. Occupancy is expected to be about 10 personnel during normal power operation and up to 100 during outage. Fire risk profile of BWX, determined by BS 9999 (Ref. 5), is assessed as A2 due to a medium fire growth rate. Two-way travel is available from most areas providing compliant escape distances in the majority of situations.

150. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety assessment of the Radioactive Waste Treatment Building. Departures from this guidance are also recorded by the RP in document submissions as a gap. I assessed each gap, using fire engineering principles to ensure suitable mitigation is in place and risks are adequately controlled and reduced ALARP.

151. Detailed assessment started in Step 4 of the GDA process with submission of the Fire Safety Strategy for the Radioactive Waste Treatment Building, Revision A. (Ref. 36). I reviewed the fire engineering contained in this initial document in March 2020. Due to departures from building design guidance contained in BS 9999 (Ref. 5), I issued RQ-UKHPR1000-0723, (Ref. 28), relating to staircase arrangements. The fire engineering detailed in the original Fire Safety document was superseded by submission of revision B of the Fire Safety Strategy, (Ref. 19). The RQ was closed out by submission of the updated document which improves the risk assessments and enhances fire safety arrangements.

152. RQ-UKHPR1000-0723 - Staircase Arrangements - Radioactive Waste Treatment Building, (Ref. 28). I raised this RQ due to the arrangement of staircases within the shafts which did not meet the recommendations contained within BS 9999, (Ref. 5). The issue arose because people escaping from the staircase serving the upper floors were required to pass through the head of the basement staircase before they could reach a place of safety. The original design led to the potential that smoke from a fire in the basement could enter the staircase and prevent escape from the floors above ground. The full response to the RQ acknowledged the issue and proposed a review of means of escape. The RQ was closed out by submission of an update to the Fire Safety Strategy for the Radioactive Waste Treatment Building to Revision B, (Ref. 19), which incorporates a redesign of the staircase arrangements and improves means of escape.

153. RQ-UKHPR1000-0952 -Clarity of Impact Assessment - Radioactive Waste Treatment Building, (Ref. 28). This RQ was issued after review of an early version of a proposed update to the Fire Safety Strategy document which intended to close out concerns raised in a previous RQ-UKHPR1000-0723. The draft update described several options to prevent smoke from a fire in the basement of the building affecting escape from the upper levels, however, the reasoning to support the final design choice was not clear. The submission of revision B of the Fire Safety Strategy for the Radioactive Waste Treatment Building, (Ref. 19), closed out this RQ by clarifying the option selected and addressing the fire engineering issues that initiated this line of enquiry.

154. The Fire Safety Strategy for the Radioactive Waste Treatment Building, Revision B, (Ref. 19), submitted in August 2020 incorporates the structural modifications that resolve and close out the issues raised in RQ-0723 Staircase Arrangements, (Ref. 28).

This update defines the fire protection arrangements and how the building and its occupants are expected to react, should a fire occur. The Strategy describes both conventional fire precautions that are applicable to the whole building and the fire engineering undertaken to manage gaps arising from individual fire compartments that depart from compliance with relevant good practice. Although several gaps for the BWX were resolved by the RQs arising from earlier submissions, this updated document describes the management of the remaining departures from relevant good practice. The Strategy document describes suitable arrangements to satisfy legal requirements and meet GB expectations for industry good practice in fire safety design. Areas which depart from BS 9999 (Ref. 5), are detailed in the paragraph below.

The Strategy document identifies 7 residual Gaps from British Standard 9999 (Ref. 5), which are categorised into three groups of similar type for fire engineering assessment.

155. Inner-inner room conditions

Gaps 1 & 2. Dead-end compartments BWX0911ZRM and BWX0919ZRM, were inner rooms that departed from design guidance due to the arrangement of multiple access rooms. The Strategy describes the fire engineering assessment which resolved means of escape by design alterations that add a new shield wall and exit door from compartment BWX0934ZRM. The modification removes the gap and meets the expectations of BS 9999 (Ref. 5).

156. Gap 3. Dead-end compartment BWX1559ZRM, was an inner room that departed from design guidance for means of escape due to the arrangement of multiple access rooms. The Strategy describes the fire engineering assessment which resolved means of escape by design alterations that removed the wall between BWX1520ZRM and BWX1522ZRM thereby reducing the number of compartments and extending the access corridor. The modification removes the gap and meets the expectations of BS 9999 (Ref. 5).

157. Staircase fire protection

Gap 4. Staircase BWX0901SFA/BWX2001SFA discharged into an unprotected corridor and not to a place of safety as recommended in good practice for fire safety design. To resolve this issue, the RP has changed the design to form a protected corridor leading to the lobby of the supervised area. The modification resolves the gap and satisfies the expectations of BS 9999 (Ref. 5). The new exit route from Controlled Area to the Supervised Area is restricted, in normal circumstances, by a door release mechanism which operates on activation of fire alarm.

158. Gap 5. Staircase BWX2003SFA discharged into an unprotected anteroom and not to a place of safety. This gap from BS 9999 (Ref. 5), was resolved by the RP fire protecting the ante room BWX2045ZRM through cable wrapping and the addition of overpressure from the ventilation system. These alterations remove the gap and bring the staircase discharge arrangements into compliance with industry good practice.

159. Staircase segregation

Gap 6 & 7. Staircases BWX2001SFA and BWX2002SFA which serve the upper floor levels of BWX, discharged at access level, through the head of the staircase from the basement. The original arrangement failed to meet relevant good practice which expects basement staircases to be segregated from staircases accessing upper levels to restrict the potential for smoke arising from a fire in the basement, affecting escape from higher floors. The Strategy describes the fire engineering assessment which resolved means of escape by design alterations that exchange the position of the staircases from the upper levels with the position of the staircases from the basement. The modification removes the gap and achieves compliance with BS 9999 (Ref. 5).

4.6.2 Strengths

160. The RP has implemented a significant number of modifications including redesign of staircase arrangements within the Radioactive Waste Treatment Building that reduce the risk to people from the danger of fire. These structural alterations to improve fire protection for five staircases and other modifications to remove unsatisfactory dead-end conditions and extended escape distances provide real safety benefit.

The number and scale of modifications demonstrates the RP's commitment to reduce risk gaps and drive safety

4.6.3 Outcomes

161. The modifications to BWX implemented during GDA, has resulted in a facility that is compliant with the recommendations for relevant good practice in building design for fire safety.

4.6.4 Conclusion

162. Based on the outcome of my conventional fire safety assessment of the Radioactive Waste Treatment Building, I have concluded that the formal submissions and full responses to Regulatory Queries, indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

163. Fire Safety arrangements within the Radioactive Waste Treatment Building conform to relevant good practice, British Standard 9999 (Ref. 5).

4.7 Diesel Generator Buildings Fire Safety Design Assessment.

4.7.1 Assessment

164. My assessment of the Diesel Buildings refers to BDA, BDB, BDC, BDU and BDV. These five independent buildings are based on two separate designs; BDA, BDB and BDC are identical; BDU and BDV are identical. In all cases the function of the buildings is to house a single diesel generator and fuel tank with the capability of producing electrical power for a sustained period. One-hour structural fire resistance is provided to the boundary of fire compartments with two-hour standard for the main fuel tank. The buildings height ranges from floor levels at -11.3m to +20m. A single, pressurised, fire protected staircase is provided in each building. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout each facility. Other fire protection measures include a fixed firefighting system and smoke extraction system. Occupancy in the diesel buildings is normally restricted to inspection and maintenance, typically reaching a maximum of 15 but during outage this number of people could increase to about 50. BS 9999 (Ref. 5), fire risk profile is assessed as A3 due to a potential fast fire growth rate.

165. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety design of the Diesel Building. Departures from this guidance are also recorded in the document submissions by the RP as a gap, and I assessed each gap using fire engineering principles to ensure suitable mitigation is in place and risks are adequately controlled and reduced to ALARP.

166. Fire Safety Strategy for the Diesel Generator Building, Revision A, (Ref. 37), was the initial submission for these five buildings which commenced GDA fire safety assessment in Step 4. I reviewed the fire engineering contained in the document in June 2020 and due to departures from recommendations contained in BS 9999 (Ref. 5), I issued RQ-UKHPR1000-0965, (Ref. 28), which challenged the provision of alternative directions of escape and RQ-UKHPR1000-0966, (Ref. 28), which queried the fire protection for continuous staircases. The full responses to the RQs described building modifications and further information to support the fire engineering claims. Submission of an updated Strategy document to revision B (Ref. 20) confirms the structural modifications which close out the issues raised by the RQs and supersedes the fire engineering in the original Fire Strategy.

167. RQ-UKHPR1000-0965 - Alternative direction of escape not achieved. (Ref. 28). This RQ related to proposals in the original Fire Strategy document to improve means of escape from a room BDA2812ZRM with two gaps from BS 9999, (Ref. 5), recommendations. These gaps comprised an extended escape distance and unsatisfactory inner room condition. The original strategy proposed to remove the gaps by introducing a new route avoiding the dead-end situation. I challenged these proposals because both the existing route and the new route joined together in room BDA2802ZRX where a fire in the common room prevents escape via either of the two directions. The full response to the RQ proposed to re-evaluate and improve means of escape from room BDA2812ZRM. The issue was fully closed out with the later submission of an update to the Diesel Building Fire Safety Strategy - revision B, (Ref. 20), which confirmed structural modifications that removed the gap.

168. RQ-UKHPR1000-0966 - Fire Protection Arrangements for Continuous Staircases. (Ref. 28). The original fire safety strategy document did not include an assessment of the fire protection arrangements for the single continuous staircase that serves the upper floors and basement levels. Relevant good practice in the fire safety design of buildings of this size recommends basement stairs are segregated from staircases to upper levels. Full response to RQ-UKHPR1000-0966 resolved means of escape issues and removed the gap from compliance with BS 9999 (Ref. 5), by implementing structural modifications to segregate basement access staircase from upper levels. The RQ was fully closed out with confirmation of measures to improve means of escape in the updated Fire Safety Strategy to revision B, (Ref. 20).

169. Fire Safety Strategy for Diesel Generator Building Rev B, (Ref. 20), defines the fire protection arrangements and how the building and its occupants are expected to react, should a fire occur. The document describes both conventional fire precautions that is applicable to the whole building and the fire engineering undertaken to manage gaps arising from individual fire compartments that depart from compliance with relevant good practice. Revision B of the Fire Safety Strategy for Diesel Generator Building, (Ref. 20), includes the building modifications that resolve RQ-UKHPR1000-0965-Alternative direction of escape not achieved, (Ref. 28), and RQ-UKHPR1000-0668-Fire Protection Arrangements for Continuous Staircases, (Ref. 28).

170. The Strategy describes suitable arrangements to satisfy legal requirements and meet GB expectations for industry good practice in fire safety design. Although several gaps for the Diesel Buildings were resolved by the RQs arising from earlier submissions, this updated document describes the management of the remaining departures from relevant good practice. The document identifies 25 residual Gaps from British Standard 9999 (Ref. 5), which are categorised into three groups of similar type and are subject to detailed fire engineering assessment. These departures from BS 9999 (Ref. 5), are detailed in the paragraphs below.

171. <u>Extended escape distances</u>

Gaps 1 - 3. Compartments BDA1601ZRM, BDC1601ZRM and BDB1601ZRM have a single direction of escape that exceeds BS 9999 (Ref. 5), recommendations for maximum travel distance by less than 5m. Following a fire engineering assessment described in revision B of the Fire Safety Strategy for the Diesel Buildings (Ref. 20), the existing design is maintained. I am satisfied that the RP has demonstrated that the risks are reduced ALARP based upon the following factors: -

- Protected escape staircase.
- Limited fire load from cable trays with low rate of spread of flame along the escape route.

- Limited occupancy.
- Automatic fire detection.
- Slight extension of escape distance.

172. Gaps 4 – 6. Compartments BDA2501ZRM, BDC2501ZRM and BDB2501ZRM had a single direction of escape that exceeded BS 9999 (Ref. 5), travel distance recommendations by less than 7m. Ventilator Room BDA2501ZRM is assessed as the bounding case. Following a fire engineering assessment described in revision B of the Fire Safety Strategy for the Diesel Buildings (Ref. 20), means of escape from the area is improved by a modification which involves repositioning the access ladder to the area and providing a new exit door into the escape staircase. The alteration brings the escape distance within guidance for good practice and removes the gap.

173. Gaps 7 - 12. Compartments BDA2806ZRM, BDB2806ZRM and BDC2806ZRM all have the same layout; the arrangement of compartments BDA2812ZRM, BDB2812ZRM, and BDC2812ZRM is also similar. These two groups of rooms had a single direction of escape that exceeded BS 9999 (Ref. 5), travel distance recommendations by less than 3m. BDA2812ZRM prefilter ventilation room, is assessed as the bounding case in revision B of the Fire Safety Strategy for the Diesel Buildings (Ref. 20). Means of escape is improved by implementation of structural modifications to form a new corridor with direct access into the escape staircase. The construction of the corridor removes the gap arising from the slightly extended escape distance and also resolves unsatisfactory inner room conditions described in Gaps 13 – 18.

174. <u>Inner-inner rooms</u>

Gaps 13 -18. Dead-end compartments BDA2812ZRM, BDA2813ZRM, BDC2812ZRM, BDC2813ZRM, BDB2812ZRM, and BDB2813ZRM, were inner rooms that departed from design guidance due to the arrangement of access rooms. The Strategy document describes the fire engineering solution to resolve gaps arising from extended escape distances, detailed immediately above, which also removes the unsatisfactory inner room conditions of gaps 13 -18 and brings the layout into compliance with the expectations of BS 9999 (Ref. 5). The modification includes the construction of the new corridor which gives direct access to an escape staircase.

175. Gaps 19 & 20. Dead-end compartments BDU2809ZRM and BBDV2809ZRM, were inner rooms that departed from design guidance due to multiple access rooms. Following a fire engineering assessment described in revision B of the Fire Safety Strategy for the Diesel Buildings (Ref.20), means of escape is improved by the formation of a new escape route through the tank room. This structural alteration resolves the inner room condition and brings the layout into compliance with the expectations of BS 9999 (Ref. 5).

176. <u>Staircase fire protection</u>

Gaps 21 – 23. Staircases BDA0801SFA, BDB0801SFA and BDC0801SFA are the single escape routes from each of these three buildings. The initial design of the staircase does not meet relevant good practice because the stair was continuous from basement to upper levels with no segregation at the ground floor. Segregation of the staircases at building access level ensures that smoke from a fire in the basement will not prevent escape from higher floors. This issue was originally identified in RQ-UKHPR1000-0966, (Ref. 28). Revision B of the Fire Strategy for the Diesel Building, (Ref. 20), implements the structural alterations involving addition of a fire resisting door and wall to effectively separate the basement staircase from the staircase to upper levels which removes the gap and meets the expectations of BS 9999 (Ref. 5).

177. Gaps 24 & 25. Staircases BDU0801SFA, BDV0801SFA are single escape routes from each of these two buildings. These two gaps were very similar to the cases described above because the staircase is continuous from basement to upper levels and there was no segregation at ground floor. The two staircases are brought into compliance with BS 9999 (Ref. 5) recommendations by design modifications implemented in Revision B of the Fire Strategy for the Diesel Building, (Ref. 20). The structural alterations separate the staircases using a fire resisting door and partition at the head of the basement staircase to protect escape from the upper levels.

4.7.2 Strengths

178. The modifications implemented by the RP to the Diesel Buildings reduce the risk to people from the danger of fire. Structural alterations to improve fire protection for staircases and other modifications that remove unsatisfactory dead-end conditions and extended escape distances provide real safety benefit.

179. The number and scale of modifications demonstrates the RP's commitment to reduce risk gaps and drive safety.

4.7.3 Outcomes

180. The modifications implemented by the RP, has resulted in a facility that is compliant with the recommendations for relevant good practice in building design for fire safety and the few remaining areas which depart from guidance are fully assessed and the RP has adequately demonstrated risks are controlled and reduced ALARP.

4.7.4 Conclusion

181. Based on the outcome of my conventional fire safety assessment of the Diesel Building, I have concluded that the formal submissions and full responses to Regulatory Queries, indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

182. Fire Safety arrangements within the Diesel Building conform to relevant good practice, British Standard 9999 (Ref. 5), and for areas which depart from compliance with this guidance, adequate fire engineered mitigation is in place.

4.8 Personnel Access Building Fire Safety Design Assessment.

4.8.1 Assessment

183. My assessment of the Personnel Access Building refers to BPX. The building is divided into a Controlled Area and a Supervised Area with limited connections between the two areas. BPX consists of three floors from 0.00m to +8.70m served by four pressurised escape staircases. The main fire load arises from insulation of electrical cables, electrical control cabinets and laundry rooms. Occupancy of the Personnel Access Building is mainly transient, typically less than 10 and during outage the maximum number of people is expected to be about 50. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout the facility and the fire risk profile, according to BS 9999 (Ref. 5), is evaluated as A2 due to the medium fire growth rate.

184. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety design of the Personnel Access Building. Departures from this

guidance are recorded in the Strategy document as a gap, and I assessed each gap, using fire engineering principles to ensure suitable mitigation is in place, risks are adequately controlled and reduced to ALARP.

185. Fire Safety Strategy for the Personnel Access Building, Revision A, (Ref. 21), was submitted in Step 4 and reviewed July 2020. The fire engineering contained in the Fire Safety Strategy identified two departures from recommendations contained within BS 9999 (Ref. 5); the first gap concerned rooms with extended escape distances and the second gap related to staircases which did not discharge into a place of safety. After I reviewed the Strategy document, I raised RQ-UKHPR1000-0967, (Ref. 28), because one staircase was not included in the list of gaps related to fire protection of staircases. This RQ was later closed out by submission of revision C of the site-wide ‘High Level Fire Safety Strategy’ document, (Ref. 10), which confirms provision of a new exit route discharging directly to open air.

186. RQ-UKHPR1000-0967 - Staircase Fire Protection – Personnel Access Building, (Ref. 28). This RQ was raised for staircase BPX2003SFA which discharges into an unprotected area on the ground floor of BPX. Other similar staircases in the Personnel Access Building with this original configuration were identified in the Fire Safety Strategy for the Personnel Access Building, Revision A, (Ref. 21), as a gap from compliance with BS 9999 (Ref. 5), and measures were implemented to protect the staircases. The full response to RQ-UKHPR1000-0967 acknowledges the departure and details a structural alteration which provides a new exit door from the staircase enclosure, direct to open air. Confirmation of the arrangements is closed out by submission of the updated site wide ‘High-Level Fire Safety Strategy’ document to revision C, (Ref. 10). The modification, which involves adding an exit from the staircase enclosure, removes the gap and meets the expectations of relevant good practice, BS 9999 (Ref. 5).

187. The Fire Safety Strategy for BPX defines the fire protection arrangements and how the building and its occupants are expected to react, should a fire occur. The document describes both conventional fire precautions that are applicable to the whole building and the fire engineering undertaken to manage gaps arising from individual fire compartments that do not meet relevant good practice, BS 9999 (Ref. 5). The Strategy document describes suitable arrangements to satisfy legal requirements and meet GB standards and relevant good practice in fire safety design. Although the full response to the RQ for BPX resolved one gap, the Fire Strategy document identifies 2 remaining Gaps which depart from BS 9999 (Ref. 5), which are assessed individually in the paragraphs below.

188. <u>Extended escape distance</u>

Gap 1. Compartment BPX2421ZRX was an office, with a single direction of escape that exceeds BS 9999 (Ref. 5), recommendations by over 4m. Following a fire engineering review during the development of the Strategy, means of escape is resolved by adding a door on the wall between BPX2421ZRX and BPX2413ZRX, thereby forming an alternative escape route. The modification removes the gap and meets BS 9999 (Ref. 5) recommendations for escape distances.

189. <u>Staircase discharge arrangements</u>

Gap 2. Staircase BPX2001SFA failed to meet good practice in design for fire safety because it discharged at access level into an unprotected area. BS 9999 (Ref. 5) recommends that fire protected staircases discharge directly to a place of safety or to a fire protected escape route. Following fire engineering review by the RP, the Fire Safety Strategy for BPX implements a modification adding a new fire exit from the staircase enclosure which discharges directly to open air. The design alteration is recorded in the 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23).

190. A similar staircase to Gap 2 above, BPX2003SFA was the subject of RQ-UKHPR1000-0967, (Ref. 28), due to it discharging into an unprotected area. The full response to the RQ proposed to solve the issue in a comparable manner to Gap 2, by the provision of a new exit a ground floor level. In both cases structural alterations remove the gaps and comply with BS 9999 (Ref. 5) for staircase fire protection. The 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23), confirms the provision of these new exit routes.

191. In summary, the Fire Strategy for the Personnel Access Building – Rev A, (Ref. 21), supported by 'ALARP Demonstration Report for Conventional Fire Safety', (Ref 23), provides a suitable and sufficient assessment of risk from fire. The modifications implemented in the design bring the building into compliance with BS 9999 (Ref. 5).

4.8.2 Strengths

192. The RP has implemented modifications within the Personnel Access Building that reduce the risk to people from the danger of fire. Structural alterations to improve fire protection for staircases and resolve extended escape distances to provide real safety benefit. The number and scale of modifications demonstrates the RP's commitment to reduce risk gaps and drive safety.

4.8.3 Outcomes

193. Modifications to the design arising from fire engineering review undertaken during the GDA process have improved fire safety and bring the building into compliance with modern standards of relevant good practice, BS 9999 (Ref. 5).

4.8.4 Conclusion

194. Based on the outcome of my conventional fire safety assessment of the Personnel Access Building, I have concluded that the formal submissions and full responses to Regulatory Queries, indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

195. Fire Safety arrangements within the Personnel Access Building conforms to relevant good practice contained within British Standard 9999 (Ref. 5).

4.9 Extra Cooling System and Firefighting Water (BEJ) Building Fire Safety Design Assessment.

4.9.1 Assessment

196. My assessment of the Extra Cooling System and Firefighting Water Building refers to BEJ. The building is designed to house equipment to remove the residual heat from the reactor core, as well as the decay heat from the Spent Fuel Pool. Additionally, BEJ provides Fire-fighting Water for the UK HPR1000 site. The building has three floors at -4.5m, 0.0m and +8.6m served by four staircases each with access to open air. Fire load in BEJ consists mainly of insulation on electrical cables. Automatic fire detection to BS 5839 (Ref. 26), is provided to an enhanced L2 specification for detector coverage throughout the facility. Occupancy during normal power operation is transient, typically less than 10 personnel but during outage numbers could increase to about 100. Fire risk profile of BEJ, determined by BS 9999 (Ref. 5), is assessed as A3 due to potential fast fire growth rate. Two-way travel is available from most areas providing compliant escape distances in the majority of situations.

197. I used British Standard 9999 (Ref. 5) as the benchmark for relevant good practice in the fire safety assessment of the BEJ Building. Departures from this guidance are recorded by the RP in the Fire Strategy document as a gap, and I assessed each gap, to ensure suitable mitigation is in place and risks are reduced to ALARP.

198. Detailed assessment of BEJ started in Step 4 of the GDA process with submission of the Fire Safety Strategy for the Extra Cooling System and Fire-fighting Building, Revision A, (Ref. 38). I reviewed the fire engineering contained in this initial document in June 2020 and subsequently issued RQ-UKHPR1000-0964, (Ref. 28). The RQ, asked for clarification on the selection of measures to improve the fire protection of staircase BEJ1503SFA. A later update to revision B of the Fire Safety Strategy, (Ref. 22), superseded and closed out fire engineering issues in the initial Strategy document.

199. RQ-UKHPR1000-964 - Clarity of Fire Strategy Document - BEJ Building, (Ref. 28). I raised this RQ because the Fire Safety Strategy document was not clear about the choice of arrangements to improve the fire protection of staircase BEJ1503SFA. The full response acknowledged the issue raised in the RQ and gave a clear description of the additional measures to improve means of escape by structural alterations that add a fire resisting lobby at the access level. Submission of an update to the Fire Safety Strategy for BEJ Building to revision B, (Ref. 22), implemented the design modifications and closed out the RQ.

200. The Fire Safety Strategy for the BEJ Building, Revision B, (Ref. 22), updates the earlier Strategy for BEJ Building and implements the measures to close out RQ-UKHPR1000-964 described above. The document defines the fire protection arrangements and how the building and its occupants are expected to react should a fire occur. The updated Strategy describes both conventional fire precautions that are applicable to the whole building and the fire engineering undertaken to manage gaps arising from individual fire compartments that depart from compliance with BS 9999 (Ref. 5). The Strategy document describes suitable arrangements to satisfy legal requirements and meet GB relevant good practice in fire safety design. Although a gap for the BEJ was resolved by the RQ arising from earlier submissions, this updated Strategy document describes the management of the remaining departures from relevant good practice. Areas which depart from BS 9999 (Ref. 5), are detailed in the paragraph below.

The Strategy document identifies 4 remaining Gaps from British Standard 9999 (Ref. 5), which are subject to a fire engineering assessment.

201. <u>Extended escape distances</u>

Gap 1. Compartment BEJ1508ZRM had a single direction of escape that exceeded recommendations for travel distance by over 16m. Following a fire engineering assessment by the RP, means of escape is resolved by upgrading an existing staircase to form a protected escape staircase at -4.5m level. The modification resolves the extended escape distance by producing an alternative escape route. This removes the gap and satisfies the recommendations of BS 9999 (Ref. 5).

202. <u>Staircase discharge arrangements</u>

Gaps 2 – 4. Staircases BEJ1501SFA, BEJ1502SFA and BEJ1503SFA originally did not meet good practice in design for fire safety because they discharge at access level into an unprotected area. BS 9999 (Ref. 5) recommends that fire protected staircases discharge directly to a place of safety or to a fire protected escape route. The Fire Safety Strategy implements modifications to protect the exit from each staircase by the addition of a fire protected lobby at access level. The alterations remove the gap and bring the staircase arrangements into compliance with relevant good practice, BS 9999 (Ref. 5).

4.9.2 Strengths

203. The RP has implemented modifications within BEJ Building that reduce the risk to people from the danger of fire. Structural alterations to improve fire protection for staircases and resolve extended escape distances provide real safety benefit. The number and scale of modifications demonstrates the RP's commitment to reduce risk gaps and drive safety.

4.9.3 Outcomes

204. Modifications to the design, arising from development of the fire safety strategy, have improved fire safety and bring the building into compliance with modern standards of relevant good practice, BS 9999 (Ref. 5).

4.9.4 Conclusion

205. Based on the outcome of my conventional fire safety assessment of the BEJ Building, I have concluded that the formal submissions and full responses to Regulatory Queries, indicate that the design will satisfy GB legal requirements for the protection of people from the danger of fire.

206. Fire Safety arrangements within the BEJ Building conforms to relevant good practice contained within British Standard 9999 (Ref. 5).

4.10 Demonstration that Relevant Risks Have Been Reduced to ALARP

4.10.1 Assessment

207. The 'ALARP Demonstration Report for Conventional Fire Safety', Rev. C, (Ref. 23), is a summary document that describes the evolution of the fire engineering assessments of UK HPR1000 buildings throughout the GDA process. My evaluation that risks are reduced ALARP is based upon the detailed fire safety assessments and original source material submitted by the RP, that is: - Building Fire Safety Strategies; Gap Management Reports, and; full responses to RQs. The ALARP Demonstration Report correctly references this information, and it presents an accurate overview of the key measures that provide fire protection for conventional fire safety.

208. The Regulatory Reform (Fire Safety) Order 2005, (Ref. 9) places duties on the 'responsible person' to ensure adequate arrangements for the protection of people from the danger of fire. The legislation is non-prescriptive and goal setting in the approach to achieving safety. Structural arrangements for providing adequate means of escape in the design of buildings that meet the requirements of the Regulatory Reform (Fire Safety) Order 2005, (Ref. 9), can be achieved in several ways. In the case of a new nuclear power plant, the recommendations contained within both BS 9999 (Ref. 5) and BS 7974, (Ref. 6) are relevant good practice for fire safety design. These codes of practice also take into account the use of non-structural fire protection measures, where necessary, to enhance or mitigate fire safety arrangements.

209. I have assessed the generic UK HPR1000 design of all buildings, as described in my Step 3 and Step 4 GDA Assessment Plans (Ref's. 24 and 25), to confirm the 'Responsible Person', as defined in the Regulatory Reform (Fire Safety) Order 2005, (Ref. 9), can provide adequate protection for people from the danger of fire,

satisfy the means of escape requirements of the legislation and ensure adequate facilities for firefighters.

210. Each of the eight buildings in my Conventional Fire Safety assessment is provided with an individual Fire Safety Strategy document that is supported by additional material which describes the fire protection arrangements, risk assessments and fire engineering undertaken for each facility. In combination, the Strategy and supporting documents describe the fire safety arrangements that enable the licensee to satisfy the Regulatory Reform (Fire Safety) Order 2005, (Ref. 9), by demonstrating that the building has no significant departures from relevant good practice in the design for fire safety. Where the design is shown to meet the recommendations within BS 9999 (Ref. 5), an adequate level of risk control is achieved and action to reduce risk further is not needed. The demonstration that risks are reduced ALARP becomes necessary for departures from relevant good practice in fire safety design of buildings, in this case BS 9999 (Ref. 5). The suite of Fire Safety Strategy documents and relevant supporting material clearly identify and record these departures as ‘Gaps’.

211. Departures from BS 9999 (Ref. 5) are subject to a fire engineering process described in the document ‘Methodology for Gap Management in Conventional Fire Safety Area’ (Ref. 11). The document provides a structured process for the identification, management, and resolution of departures from compliance with relevant good practice and is intended to ensure consistency in fire safety design assessment and provide a record of the depth and breadth of fire engineering. One potential outcome from fire engineering is to introduce modifications to the fire protection which removes the gap and achieves compliance with BS 9999 (Ref. 5). When compliance with prescriptive guidance is not reasonably practicable, an alternative outcome of the gap management process is the production of a range of options which may include various proposals to enhance mitigation and improve fire safety or a justification that the existing arrangements are satisfactory because risk is already reduced ALARP. In all cases, each option is assessed for its benefit to life safety, impact on nuclear safety, operational considerations, and cost.

212. When evaluating the optimal solution from a range of fire protection measures to address identified gaps, the Gap Management process uses a multi-attribute scoring system which records priorities allocated to Conventional Fire Safety, nuclear safety, operational impact, and cost. Various weighting factors are applied to these categories. Finally, the optimal fire engineering solution is selected by the option achieving the highest total score and the document claims to demonstrate risks are reduced ALARP. However, in my assessment of the most suitable fire engineering option, I did not consider the scores presented by the RP but instead, I took into account experience of relevant industry good practice in the resolution of unique challenges to fire safety through the application of Fire Engineering principles, and cognisance of nuclear safety and security requirements. Despite these alternative approaches between myself and the RP, there was generally an agreement in the results of the optioneering undertaken in the Impact Analysis. Where there was a misalignment of opinion, I raised an RQ.

213. My assessment reviewed all submissions for compliance with BS 9999 (Ref. 5). I also evaluated the application of the management process for areas which depart from this guidance to ensure risks were fully assessed and adequate mitigation was in place for the protection of people from the danger of fire. I raised RQs at any point where in my judgement risks were not reduced ALARP, and followed-up the full responses. Close out of issues raised in RQs was only deemed to be achieved when further improvements to fire safety arrangements were developed or more suitable and sufficient risk assessments were undertaken which contained enhanced fire engineering detail and robust justifications. In cases where the full

response did not satisfy my challenge, then subsequent RQs were issued, and the process repeated. When structural alterations were necessary to provide appropriate safety improvements, close out of the issue was deemed to be achieved upon formal submission of an update to an existing fire safety document with confirmation of the modifications.

214. Within the GDA Conventional Fire Safety assessment process of formal document submissions, the RP identified a large number of gaps from compliance with BS 9999 (Ref. 5), and in all cases successfully made a compelling argument that residual risks were reduced ALARP. Where I raised RQs related to departures from guidance, close out of the issue was also achieved with a successful demonstration that risks were reduced ALARP. These criteria were met for every gap in each building and there are no outstanding departures from relevant good practice exhibiting inadequate mitigation or inadequate risk assessment. I am satisfied that the fire safety document submissions for the generic UK HPR1000 design, as described in preceding paragraphs, demonstrate that the assessments of conventional cire safety risks are suitable and sufficient, appropriate control measures and suitable mitigation is in place, and risks are reduced ALARP.

4.10.2 Strengths

215. Each building on the nuclear island comprising the generic UK HPR1000 design is supported by a suitable and sufficient risk assessment that benchmarks fire safety design against BS 9999 (Ref. 5) and demonstrates that where departures from relevant good practice occurs, risks are reduced ALARP. To achieve this position, the RP has implemented a large number of modifications to the original design. In some cases, improvements to safety have been gained by introducing non-structural alterations but there are also examples of significant design changes; alterations to internal layouts; construction of additional escape routes; extra final exit doors; new fire resisting compartments, and; inclusion of additional escape staircases. These structural modifications are passive safety measures that require minimal management oversight, are largely resilient to occupant behaviour, and will remain effective throughout the life of the building. Incorporating fire safety measures into the design of a building at planning stage is far more efficient and effective than retrofitting secondary, often less effective, mitigation at a later phase in construction.

4.10.3 Outcomes

216. The generic UK HPR1000 design achieves majority compliance with modern design expectations for fire safety in building design by modifications developed during the GDA process. The few areas of departure from BS 9999 (Ref. 5), are adequately justified by a robust fire engineering assessment to effectively demonstrate risks are reduced ALARP.

4.10.4 Conclusion

217. I am satisfied that the generic UK HPR1000 design meets GB legal requirements; the risk from fire is fully assessed; adequate arrangements are in place to protect people from the danger of fire, and suitable facilities are provided for firefighters.

4.11 Consolidated Safety Case (Chapter 25)

4.11.1 Assessment

218. The nuclear safety case and conventional fire safety case have very different priorities but there are common factors; measures to reduce potential ignition sources and arrangements that restrict fire growth are relevant to both disciplines.

The main focus of Conventional Fire Safety is to ensure people can evacuate from a building to a place of safety within a limited period of time before a fire can grow and place people in severe danger. Within building design assessment, the structural arrangements that contribute to providing adequate means of escape are the priority in the hierarchy of risk control contributing to the fire safety case. These design features are not relevant to nuclear safety. Although nuclear and fire safety cases are largely independent from one another, it is essential that the requirements of both are considered in combination to ensure the design is holistically safe. For the conventional fire safety case, adequate structural arrangements are achieved when compliance with relevant good practice for fire safety design is demonstrated. Nuclear safety and security requirements are prioritised in design specifications and have resulted in some areas of the generic UK HPR1000 design varying from GB expectations for fire safety. However, the RP has utilised a robust fire engineering process to manage these 'gaps', to reduce risks ALARP, and to provide alternative mitigation to ensure the fire safety case is convincing.

219. The Production Strategy for Conventional Fire Safety, Rev. F, (Ref. 39), is a summary document that records the development of the generic UK HPR1000 safety case for protection of life from the danger of fire. The document specifies the objective of achieving compliance with UK legislation for fire safety and reducing risk to ALARP. Appropriate design guidance and fire safety standards are described in the document including organisational arrangements, detail of the procedures used to implement the measures, and methods to achieve a safe result. The Production Strategy lists all relevant documents which meets my expectations for presenting a complete fire safety case.

220. Fire safety improvements, arising from modifications described in the full responses to RQs, are already consolidated with the various individual building fire strategy documents. Consequently, the safety case is effectively presented without the need to reference RQs; building strategy documents present a coordinated account of relevant fire engineering. The fire safety case is adequately presented by the documents described in more detail below.

221. The Fire Safety Case presented by the RP is contained within a hierarchical suite of documents that developed throughout the GDA process. The fire safety case commences within Chapter 25 of the PCSR (Ref. 3) which describes the overall policy to provide a fire safe power plant. The suite of documents includes a site-wide 'High-Level Strategy' document (Ref. 10), which describes how the policy will be delivered and at a lower level, bespoke Fire Safety Strategy documents for each individual building which are supported by additional material that addresses fire safety provisions for single fire compartments.

222. Chapter 25 of the PCSR (Ref. 3) is a high-level document that states the policy to comply with GB fire safety legal requirements and ensure adequate arrangements are in place to protect people from the danger of fire. The document correctly references appropriate legislation and identifies relevant good practice and nationally recognised published guidance for fire safety in the design of buildings.

223. The 'High Level Fire Safety Strategy', Revision C, (Ref. 10) applies to all facilities on the nuclear island and it describes, in greater detail than the PCSR, how the generic UK HPR1000 design will achieve compliance with GB legal requirements. This document defines the approach taken to ensure the safety of occupants for each building and takes into account the specific features of individual facilities that require discrete fire protection arrangements. The 'High Level Fire Safety Strategy', (Ref. 10), identifies the correct standards relevant to delivery of the fire safety measures for the generic UK HPR1000 design and describes the implementation and application of the arrangements. The strategy confirms use of BS 9999 (Ref. 5)

which is considered relevant good practice in the design of buildings for fire safety to ensure adequate safety arrangements are realised. The document recognises the interaction and interdependencies of GB fire safety legislation including the Building Regulations 2010 and the requirements of the Regulatory Reform (Fire Safety) Order 2005, (Ref. 9).

224. The ‘Methodology for Gap Management in Conventional Fire Safety Area’ (Ref. 11) details the procedures intended to address departures from guidance in the design of buildings for fire safety. In certain cases, the multiple and complex design requirements of an operating nuclear power plant prevent full application of prescriptive guidance and alternative fire engineered methods are required to achieve an adequate level of safety and reduce risks to ALARP. The document describes a structured process for the correct identification, consistent management, and justified resolution of departures from compliance with BS 9999 (Ref. 5). The ‘Methodology for Gap Management’ (Ref. 11) references BS 9999 (Ref. 5) as relevant good practice, for fire safety in the design use and management of buildings, and the application of fire engineering principles contained in BS 7974, (Ref. 6). The procedure, developed early in the GDA process, is both an effective and useful fire safety design assessment tool, which records the depth and breadth of fire engineering undertaken to support claims that risks are adequately assessed and controlled.

225. Fire Safety Strategy documents are available for each individual building on the nuclear island. These documents describe the fire safety concepts employed to protect people and how the building is expected to perform should a fire occur. The Strategies are comprehensive and take into account; the relevant features of each building; its use in normal operation and during maintenance, and; the building’s occupancy, fire load and growth characteristics, protective measures and structural arrangements providing means of escape. The Fire Safety Strategy makes reference to compliance with appropriate legislation and uses relevant good practice in the selection of fire safety standards and choice of guidance in the selection of fire protection. Overall, the Strategy document is effective in demonstrating the means of achieving compliance with GB fire safety legislation.

226. Gap Management Reports for each building fully describe the fire engineering assessment and mitigation for design features that did not meet codes of practice for fire safety in building design. During Step 3, Gap Management Reports were submitted as a standalone document but later the Fire Safety Strategy and the Gap Management Report were combined into a single Fire Strategy document which provided a comprehensive account of fire protection features within each facility. These Reports/Fire Strategies follow the procedure in the ‘Methodology for Gap Management in Conventional Fire Safety Area’ (Ref. 11), to accurately identify record and manage departures from BS 9999 (Ref. 5). The documents have delivered compelling justifications for alternative fire engineered solutions; they have identified appropriate mitigation and effectively demonstrated risks are reduced to ALARP. Where necessary, industry good practice for the application of fire engineering principles is employed.

227. The document, ‘Analysis of Firefighting Shafts and Staircases Pressurization Systems’ Rev A, (Ref. 8), provides evidence to support the fire safety case for some important escape routes in the generic UK HPR1000 design. This study of the impact of ventilation systems on fire protection is applicable to several buildings on the nuclear island but is particularly important for the Reactor Building. The Analysis document describes the appropriate use of relevant good practice as described in BS 12101-6, (Ref. 30).

4.11.2 Strengths

228. The conventional fire safety case is based upon a demonstration that the generic UK HPR1000 design will fully comply with GB fire safety legislation and provide adequate protection of people from the danger of fire. The suite of documents that collectively comprise the safety case, contains a suitable level of detail in fire engineering assessments and a sufficient description of fire safety arrangements to comprehensively demonstrate risks are fully assessed, adequately controlled and reduced ALARP. The fire safety policy, high level strategy, building fire safety strategy and individual compartment assessments make reference to applicable legislation and describe the means to achieve compliance and meet relevant industry good practice.

4.11.3 Outcomes

229. Modifications to the original design, in many cases, have removed challenges to means of escape from fire and improved safety for occupants. The structural alterations arising as a consequence of GDA conventional fire safety assessments include layout changes which, because they are passive measures, will retain their design safety function without the need for excessive management oversight. They will be largely resilient to occupant behaviour and remain fully effective throughout the lifetime of the facility. These structural arrangements are key measures leading towards the pinnacle of the hierarchy of risk control in conventional fire safety.

4.11.4 Conclusion

230. Rigorous assessment of the generic UK HPR1000 demonstrates that the design will enable the licensee to meet GB fire safety legislation and that the buildings meet relevant industry good practice for protection of people from the danger of fire.

4.12 Comparison with Standards, Guidance and Relevant Good Practice

231. Throughout the Conventional Fire Safety GDA process, the RP has submitted documents which make reference to the appropriate legislation, building design guidance, and relevant good practice for fire protection. All submissions, from policy level to detailed fire engineering assessments of individual compartments, have made use of principles, standards, and recommendations from nationally recognised published guidance.

232. Although the Regulatory Reform (Fire Safety) Order 2005, (Ref. 9) is risk based and largely non-prescriptive, compliance with the guidance to satisfy Building Regulations is considered relevant good practice to satisfy the Order’s requirement for structural arrangements to ensure adequate means of escape. Approved Document B to the Building Regulations, (Ref. 40); British Standard 9999 (Ref. 5), and; British Standard 7974, (Ref. 6), are all suitable approaches to satisfying the fire safety requirements of the Building Regulations. Whilst Approved Document B to the Building Regulations (Ref. 40) is most suitable for simple or traditional structures and BS 7974 (Ref. 6) is a method of demonstrating safety for complex designs, the flexibility offered by the use of BS 9999 (Ref. 5) is considered most appropriate for a new power plant. This risk-based guidance considers the level of occupants’ awareness and familiarity of the building; it takes into account the fire load and growth characteristics, various building design features and the availability of enhanced fire protection measures. The RP has selected British Standard 9999: 2017, the Code of Practice for Fire Safety in the Design Management and Use of Buildings (Ref. 5) as the principal means to demonstrate adequate provision of fire safety arrangements in the generic UK HPR1000 design. The application of this standard represents a complete methodology for ensuring life safety protection from

fire. Departures from compliance with BS 9999 (Ref. 5) are identified, recorded, and resolved, where necessary, using British Standard 7974; - Application of fire safety engineering principles to the design of buildings (Ref. 6).

233. BS EN 12101-6, (Ref. 30), is considered relevant good practice for design, specification, performance and installation of pressure differential systems for fire protection. The study of ventilation systems detailed in the Analysis of Firefighting Shafts and Staircases Pressurization Systems' Rev A (Ref. 8) makes appropriate use of this standard when benchmarking aspects of the ventilation system. The resulting information from the study is evidence that supports claims for the enhanced fire protection given by the pressure differential system in certain staircases, due to appropriate benchmarking with relevant good practice.

234. Several document submissions make reference to EPR Technical Code for Fire Protection (ETC-F), (Ref. 41), a European Industry standard for fire safety which includes measures to protect life safety from the danger of fire. This standard was not considered a suitable benchmark for my assessment because ETC-f alone, is not a complete life safety methodology and it does not consider some critical means of escape issues. However, the inclusion of information about the enhanced standards of fire protection that are defined within ETC-f was valuable, but I only considered this detail as supporting evidence for control of combustibles and fire loading, particularly on escape routes.

235. Throughout the suite of fire safety documents, the RP confirms fire detection and alarm systems will be installed in accordance with the recommendations contained within British Standard 5839-1, (Ref. 26). These proposals meet the expectations for automatic fire detection in BS 9999 (Ref. 5) which is the key standard used as a benchmark for relevant good practice in the fire safety design assessment of UK HPR1000. Additionally, confirmation of the BS 5839, (Ref. 26), fire detection system permits design flexibility for certain means of escape issues due to the detector coverage provided to enhanced standards and is important in demonstrating the overall fire protection arrangements are adequate.

236. Other industry best practice for the installation, testing and maintenance of fire systems are referenced in the suite of documents forming the fire safety case. These are mainly British Standards and include BS 5266-1 Emergency Lighting; BS 5499 Escape Signage; and BS 5306 Firefighting Water Mains. Whilst installation of equipment to these standards is considered relevant good practice, the detailed implementation of these standards is not part of GDA scope but a site-specific matter which will be addressed as normal regulatory business. Consequently these documents are not referenced in my report because they are not required for my assessment of the generic UK HPR1000 design.

237. Overall, the RP has selected the most appropriate relevant codes and standards for protection of people from the danger of fire. The choice of BS 9999 (Ref. 5) ensures the project is subject to a comprehensive conventional fire safety methodology that provides a benchmark for building design which determines a suitable level of fire protection for individual risk areas. The adoption of other British Standards for fire protection systems, described in the paragraphs above, will direct the selection towards the best choice of equipment, standards of installation, and certification. The familiarity of these codes of practice in the UK will facilitate ongoing testing and maintenance of fire protection systems, to high standards. The selection of British Standards for fire protection will enable the licensee to readily demonstrate legal compliance with UK fire safety legislation.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

238. This report presents the findings of my Conventional Fire Safety assessment of the generic UK HPR1000 design as part of the GDA process.

239. Based on my assessment, undertaken on a sampling basis, I have concluded the following: The suite of documents comprising the fire safety case for the generic UK HPR1000 design demonstrates that; the occupier will satisfy the requirements of GB fire safety legislation; the assessment confirms adequate arrangements are in place to protect people from the danger of fire, and; suitable facilities are provided for firefighters. The buildings meet relevant industry good practice for fire safety design and where departures from prescriptive guidance occur, suitable alternative mitigation is in place and risks are controlled and reduced ALARP.

240. Overall, based on my sample assessment of the safety case for the generic UK HPR1000 design undertaken in accordance with ONR's procedures, I am satisfied that the case presented within the PCSR and supporting documentation is adequate. On this basis, I am content that a DAC should be granted for the generic UK HPR1000 design from a Conventional Fire Safety perspective.

5.2 Recommendations

241. Based upon my assessment detailed in this report, I recommend that:

- **Recommendation 1**: From a Conventional Fire Safety perspective, ONR should grant a DAC for the generic UK HPR1000 design.

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